THE WATER SUPPLY AND SEWERAGE OF SYDNEY

Catchment Areas in use or available for Sydney Water Supply

CROOKWELL

LAKE GEORGE

GOULBURN

LAKE BATHURST

WOLLONDILLY

WARRAGAMBA

3383 Square Miles.

KOREROMBA R.

COX'S RIVER

LITHGOW

KATOOMBA

COLO

1680 Sq. Miles.

COLO R.

GROSE

250 Sq. Mls.

ERSKINE

89 Sq. Mls.

SHOALHAVEN

SHOALHAVEN R.

A. 572 Sq. Mls.

B. 1200 Sq. Mls.

INCLUDING 'A'

SHOALHAVEN RIVER

NATTAI R.

WARRENGAMBA CK.

NEPEAN R.

MOSS VALE

PENRITH

RICHMOND

WINDSOR

MACDONALD RIVER

CLYDE R.

NEPEAN

347 Sq. Mls.

7½ Sq. Mls.

3¾ Sq. Mls.

12¾ Sq. Mls.

MACQUARIE RIVULET CATCHMENT AREAS ALTERNATIVE DAM SITES

NOWRA

LAKE ILLAWARRA

KIAMA

AMERICAN CK. 6.6 Sq. Mls.

ALLANS CK. 16. Sq. Mls.

JERVIS BAY

NEPEAN UPPER CANAL

GEORGES R.

OLIVERS CK.

WORONORA

WORONORA R.

PROSPECT RESR.

PARRAMATTA

BOTANY BAY

SYDNEY

HAWKESBURY R.

BROKEN BAY

Scale of Miles

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The Water Supply and Sewerage of Sydney.

Being an account of the development and history of the water supply and sewerage systems of Sydney and the South Coast from their inception to the end of the first 50 years of control by a Board specially constituted for the purpose.

Compiled by
F. J. J. HENRY

With a Foreword by
T. H. Upton, O.B.E., M.Sc., M.C.E.,
M.Inst.C.E., M.I.E. Aust.,
President of the Metropolitan Water Sewerage and Drainage Board, Sydney.

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FOREWORD

The development of any great system, extending over many years and contributed to by a variety of minds, is inevitably a combination of improvisation to meet immediate needs and of planning with an eye on the distant future. As time passes, the improvisations disappear or are absorbed into the more general system, but they leave their marks on the latter, which not infrequently has to be adapted to them to avoid loss and expense. More and more, however, as the system expands, any temporary scheme has to be considered from the point of view of absorption into the general system, until the long range view becomes the dominating ideal.

These two principles are plainly to be seen in the history of the water supply and sewerage systems of Sydney. The generation which knew the problems at the commencement of the Board's existence fifty years ago has almost passed away, and the arguments and the considerations which gave rise to the genesis of the present day systems are unknown except to a few. Insofar as they were only of momentary importance, there is little advantage in taking cognizance of them now, but insofar as they have a lasting significance, it is important that they should not be forgotten. In human endeavours we can rarely start from scratch. What is possible for the future is very largely determined by what has gone before, and this is particularly true of the water supply and sewerage of a great metropolis.

Mr Henry has done a valuable service both for the Board and the community at large in the pages which follow. He is one of the few left of the old brigade who joined the Board's service in the initial year of its foundation and the only one who served it throughout the whole of the past fifty years of its existence, passing from the most junior rank to the highest administrative post possible to an officer of the Board. When, therefore, he retired from the office of Secretary, at the end of June, 1937, he was commissioned by the present Board with the task of writing the history of the development of the water supply and sewerage of Sydney. He has brought to his task not only a mind uniquely stored

with knowledge, but also an unabated enthusiasm and energy, and the results which are now available will, I feel confident, not only provide information for the interested ratepayer and visitor, but also guidance for those charged with the present or future responsibility of administering these or similar enterprises.

T. H. UPTON,
President.

December, 1939.

PREFACE

In the pages which follow, an attempt has been made to trace in a brief and concise manner the development of the water supply and sewerage of Sydney and suburbs from the foundation of the settlement at Sydney Cove in 1788 to the present day, and also to furnish a record of the more important phases of the development of the organisation, which completed on 25th March, 1938, a period of fifty years' control of these important services.

In doing this, two somewhat contradictory ideals have been kept in mind. The first is to supply the general reader with simple descriptions of the two systems; the other is to supply the Board's staff and others interested in the technical points associated with each work with the basic information relating to it. The general reader will need, therefore, to omit those portions of too technical a character.

In compiling this record, full advantage has been taken of the earlier handbooks issued by the Board in 1905, 1913, and 1917. Grateful acknowledgment is also made of the sympathetic interest and assistance of the President and the technical and clerical staffs of the institution.

During the fifty years of the Board's existence, something approaching £45,000,000 has been expended in the provision of these vital utility services (£27,500,000 on water supply, and over £17,000,000 on sewerage). Huge as this expenditure may appear, it represents a reasonably rather than a fully successful endeavour to keep pace with the needs and development of the metropolitan area. The controlling factor in this, as in all other cases where public works are concerned, is finance. During the first thirty-seven of its fifty years existence, the Board was dependent on successive State Governments for the wherewithal to carry out necessary works, and was thus subject from time to time to the vicissitudes of governmental finance. However, since 1925, when the Board was endowed with complete financial autonomy, much of the leeway of earlier years has been overtaken. The economic depression of 1930-32 was responsible for some of the ground regained being lost, but since 1933, with the assistance of the New South Wales Government, the Board has

been able to secure sufficient finance for a vigorous attack upon the problem of bringing the water and sewerage services to the state necessary to meet fully present-day requirements, and provide for expansion over a reasonable period ahead. As the Metropolis continues to grow and spread its tentacles farther and farther afield, the Board must keep on planning and constructing ahead of immediate requirements, and it is hoped that what is contained in this volume will be of value in making plain the principles upon which such developments must proceed.

F. J. J. HENRY.

Sydney,
December, 1939.

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CHAPTER I

THE BOARD—ITS CONSTITUTION, RESPONSIBILITIES AND PROCEDURE

For the first 54 years from the foundation of settlement in 1788, the water supply of the township of Sydney was a Government responsibility. This duty first consisted, as will be seen later, in the protection of the purity of the main source of supply, viz.—the Tank Stream, on and along whose banks the township was located, and when this became no longer possible, in bringing water from the Lachlan Swamps (situated in what is now Centennial Park) by tunnel to Hyde Park, whence supplies were drawn off from a standard into water carts and other receptacles for distribution.

In 1842, an Act (6 Vic. No. 3) was passed, incorporating the township of Sydney as a City and providing for the administration of its services by a municipal council. The control of the water supply and the responsibility for providing sewerage and drainage (which had hitherto received practically no attention) then became a function of this body, and remained so, except for a brief interregnum of three years (1854-1857), when the council was replaced by three commissioners, until 1888. By that time, and indeed for some 12 years prior, the problem of adequately providing for either water supply or sewerage had assumed metropolitan proportions, embracing other municipalities than Sydney, and the need for some body of wider franchise than the City ratepayers had become evident.

In 1880, therefore, an Act (43 Vic. No. 32) was passed, providing for the constitution of a Board of Water Supply and Sewerage, and the transfer to it of the control of the water and sewerage services of the metropolitan area. In the previous year, an Act had been passed authorising the raising of a loan for public works, in the schedule of which appeared the item—

"Sydney Water Supply: as per estimate of Mr. W. Clark } £1,086,768"

and although, as the Premier of New South Wales (Sir Henry Parkes, K.C.M.G.), who introduced the Bill of 1880 into the Legislative Assembly, was careful to point out, it did "not necessarily commit the House to any particular plan," but only "created the necessary machinery for carry-

ing out any work which may be properly authorised," it is evident that the Upper Nepean Scheme was the one prominently in mind. Its construction commenced immediately following the passage of the Act.

The Act constituted the Minister for Public Works the "constructing authority" of the approved scheme, and consequently the Board was not called into being until 1st March, 1888, when the scheme was practically completed. Then an Act (51 Vic. No. 28) was passed, implementing the suspended provisions of the 1880 Act relating to the appointment and election of the President and Members of the Board and its functioning, and on Tuesday, 9th April, 1888, following the publication in the Government Gazette of 26th March, 1888, of the names of the members who had been appointed or elected, the Board held its first meeting.

Briefly, the functions of the Board were to take over the control and management of the water supply and sewerage works which were then under construction by the Government and those which were at the time of its creation vested in and operated by the Municipal Council of the City of Sydney or any borough or municipality in the County of Cumberland. The City Council was at this time operating the Botany Swamps Water Supply Scheme from which the City and a number of the older suburbs were being supplied, and also a combined system of sewerage and drainage discharging into the Harbour at different points, while Redfern and Darlington Municipalities had also carried out certain sewerage reticulation works in order to take early advantage of the completion by the Government of the Northern and Southern Main Outfall Sewers which were then under construction.

The Act, however, imposed limitations upon the Board which almost brought it within the category of a Government department, and in this connection it is significant that one of the earliest decisions recorded in the proceedings of the original Board was that the institution should be styled "The Metropolitan Water and Sewerage Department." The word "Department" was later changed to "Board." These decisions, however, had no legal effect, as the title was set out in the original Act as "Board of Water Supply and Sewerage." (Following the constitution in 1892 of the Hunter District Board of Water Supply and Sewerage, the word "Metropolitan" was inserted at the beginning of the title to distinguish it from the Hunter District Board.) The Minister for Works remained the "constructing authority" in respect of all major works, and these did not vest in the Board or come under its control until reported complete and transferred to it by proclamation in the Government Gazette. The revenue of the Board was payable into the Treasury and formed portion of the consolidated revenue of the State. The Board was required to submit annual estimates of its proposed expenditure for salaries, wages and other working expenses to the Minister for Works and was limited in its

expenditure to such annual votes as were ultimately passed by Parliament. Estimates of proposed expenditure on such works as the Board was empowered to carry out had also to be submitted annually to the Minister for Works, and the votes subsequently passed by Parliament were as a consequence governed at times by the exigencies of governmental finance rather than by the urgency of the contemplated works. All contracts for supplies or works, sales and leases of real estate and expenditure generally were subject to Ministerial or Executive Council approval. Contracts not exceeding £100 could be entered into by the Board without prior Ministerial approval, subject to lists of these being submitted monthly for such approval. Until 1924, when Act No. 50 of that year swept away all the above limitations excepting that large purchases and sales of real estate or lengthy leases still required Executive approval, the functions of construction and finance were therefore not separated from the governmental system. This left the Board with very limited and somewhat uncertain powers apart from maintenance and administrative duties.

In practice, until 1925, the Minister for Public Works, through his departmental organisation, carried out the more important major works, and on completion, these were transferred to and vested in the Board by Gazette proclamation. Works of lesser importance, in the category of amplification works, service reservoirs, pumping stations, trunk and reticulation mains, were carried out by the Board. This system, which came to be known as the "dual control" system, was found to work most unsatisfactorily, and rendered the Board's task of keeping abreast of developments and fulfilling its responsibilities to the public, which naturally looked to it, and it alone, for maintaining satisfactory services to meet growing requirements, a very difficult one. It involved the maintenance by the "constructing authority" of a separate technical staff (the cost of which had also to be borne by the ratepayers) who were at times in conflict with the Board's staff as to requirements, design of works and method of construction. A step in the right direction was made in 1895, when Mr C. W. Darley, M.Inst. C.E., who was at the time Engineer-in-Chief for Public Works, was appointed President of the Board. The two construction staffs were amalgamated with the ultimate objective of the Board taking over the construction of main works as well as those of reticulation and maintenance. However, owing to a reorganisation of the Public Works Department in 1896 again requiring Mr Darley's services there, this arrangement was terminated and the major construction works were again entrusted to the Public Works Department. In 1918, the position was improved to some extent by the constitution by the Minister for Public Works of a Special Expert Committee (see page 77), whose duty it was to investigate and report on the major water supply

works considered necessary for a number of years ahead to meet the rapidly increasing requirements of the metropolitan area. This committee was composed of all the principal Government engineers of the day, and the President and Chief Engineer of the Board. The inclusion of the two latter afforded the opportunity for the Board's views to be given expression to from time to time. Notwithstanding this, the main disadvantages of divided responsibility and its extra cost to the country remained, and continued to invite criticism until the Act of 1924 swept it away and placed the sole responsibility for future construction of water supply, sewerage and drainage works with the Board throughout its area of operations. Certain main works, viz. Nepean Dam, Northern Suburbs Main Sewer, and the Canterbury, Campsie and Belmore Main Sewer, then in course of construction by the Public Works Department, were excepted from the immediate application of this provision, but could by proclamation in the Gazette be transferred at any time, but not later than 30th June, 1930, to the Board for completion. Advantage was taken of this proviso by the Minister for Public Works in September, 1928, when the incomplete works, together with certain of the Public Works Department's staff engaged on them, were transferred to the Board, which then assumed the full responsibility of completing them. In 1935, however, owing to developments in connection with the Unemployment Relief Schemes of the Government, an amendment of the Board's Act was made to provide legislative authority for the action of the Minister for Public Works in carrying out certain stormwater drainage works in the Board's area of operations.

Constitution of Board.

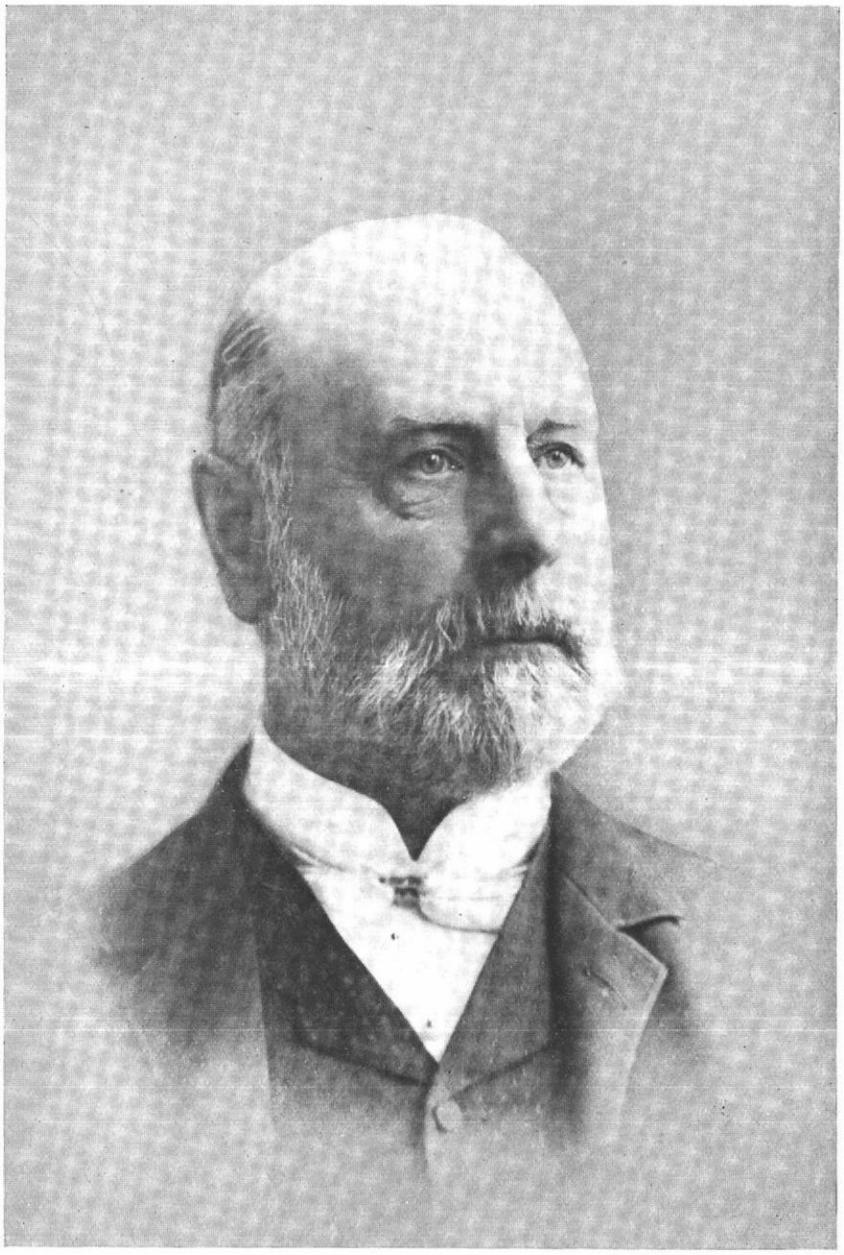
The Acts, 43 Vic. No. 32 and 51 Vic. No. 28, relating to the constitution and election of the original Board, provided for:—

(a) Appointment by the Governor of three "Official Members," one of whom was to be in and by the terms of his appointment President of the Board.

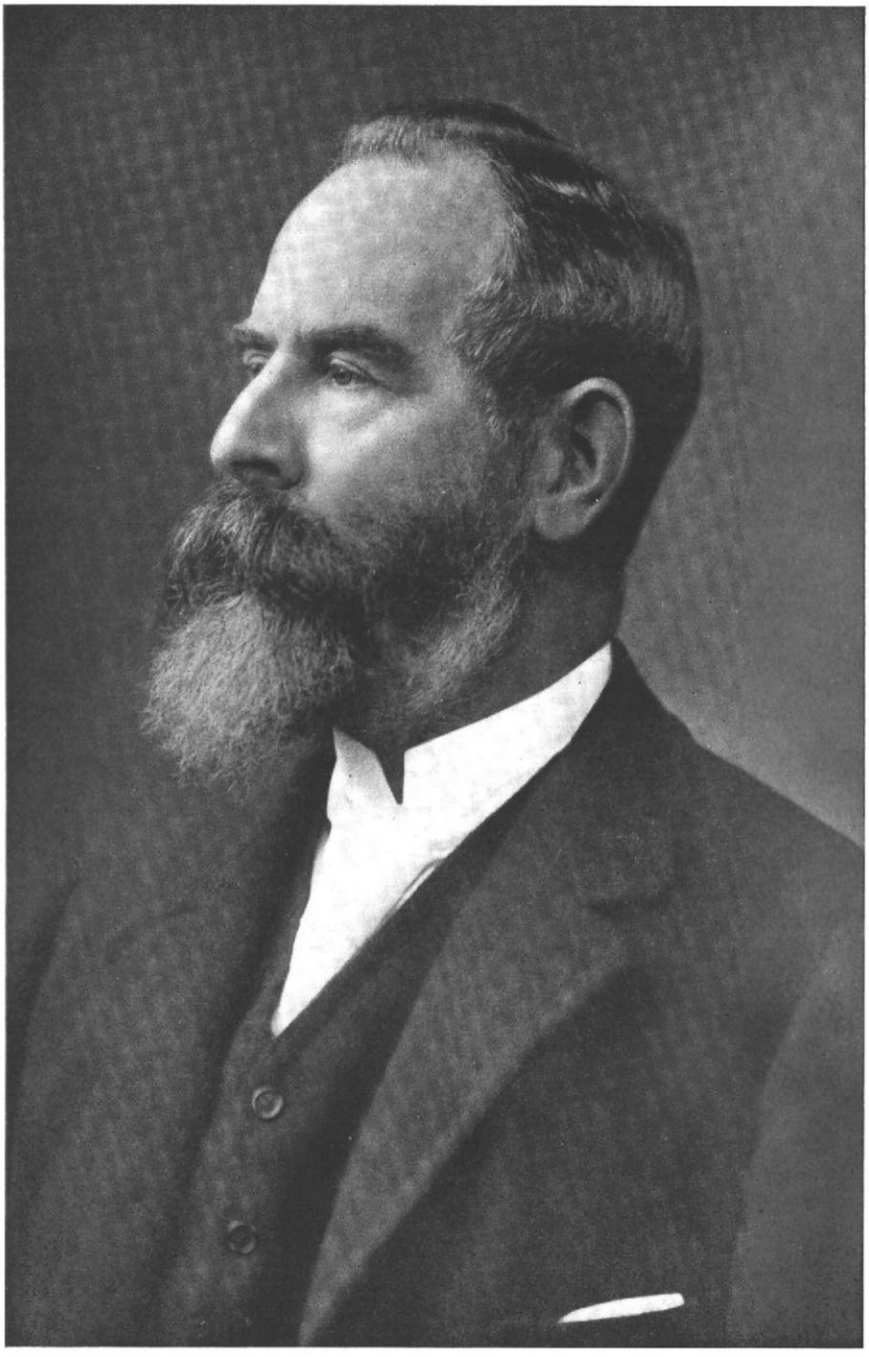
(b) Election by the Municipal Council of the City of Sydney of two Members to be designated "City Members."

(c) Election by the Mayors and Aldermen of the several boroughs and municipal districts then or thereafter to be established, situated wholly or in part within the County of Cumberland voting as one constituency, of two members to be designated "Suburban Members."

The qualification of a candidate for election was that he should at the time be qualified to become a candidate for election to one of the constituent councils. The term of office of the President was four years.



COLONEL THOMAS ROWE, F.R.I.B.A.
First President of the Board (1888-1892 and 1896-1899).



MR. C. W. DARLEY, M.INST.C.E.
Second President of the Board (1892-1896).

Of the two "Official Members," one to be designated by the Governor held office for two years, and the other for four years. Thereafter each held office for four years. Of the elected members, the original City member and the original Suburban member, who received the least number of votes at their election held office for two years, and the other two for four years. Thereafter each held office for four years. A system of retirement in rotation was thereby established under which three members retired every two years.

The following is the personnel of the successive Boards which functioned under the original constitution, 1888-1925:—

	1888-1892	
Col. Thos. Rowe, F.R.I.B.A.		President
W. C. Bennett, M.Inst.C.E.	Commissioner and Chief Engineer for Roads and Bridges	Official Member to July, 1889
R. R. P. Hickson, M.Inst.C.E.	do. do.	Official Member from July, 1889
(In succession to W. C. Bennett, deceased)		
C. W. Darley, M.Inst.C.E.	Chief Engineer, Harbours and Rivers	Official Member
Ald. B. Palmer	City Council	City Member Vice-President
Ald. J. D. Young	do.	City Member
Ald. J. Graham	Marrickville Council	Suburban Member
Ald. G. W. Lander	Redfern Council	do.
	1892-1896	
*C. W. Darley, M.Inst.C.E.		President
W. L. Vernon, F.R.I.B.A.	Government Architect	Official Member to March, 1895
G. A. Mansfield, F.R.I.B.A.	do.	Official Member from March, 1895
(In succession to W. L. Vernon, resigned)		
R. R. P. Hickson, M.Inst.C.E.		Official Member to March, 1895
Col. Thos. Rowe, F.R.I.B.A.		Official Member from March, 1895
(In succession to R. R. P. Hickson, resigned)		
Ald. B. Palmer	City Council	City Member to October, 1893
Ald. John Taylor	do.	City Member from Decr., 1893
(In succession to Ald. B. Palmer, deceased)		

* In March, 1896, shortly before the expiry of the four years' term of his appointment as President, Mr Darley resigned on taking over the duties of Engineer-in-Chief for Public Works, and Colonel Thos. Rowe was again appointed President.

Ald. J. D. Young, M.L.C.	City Council	City Member to Nov., 1893
Ald. F. Buckle (In succession to Ald. J. D. Young, deceased)	do.	City Member from March, 1894
Ald. G. W. Lander	Redfern Council	Suburban Member
Ald. J. Graham	Marrickville Council	Suburban Member to January, 1894
Ald. D. Davis (In succession to Ald. J. Graham, deceased)	Woollahra Council	Suburban Member from March, 1894

1896-1900

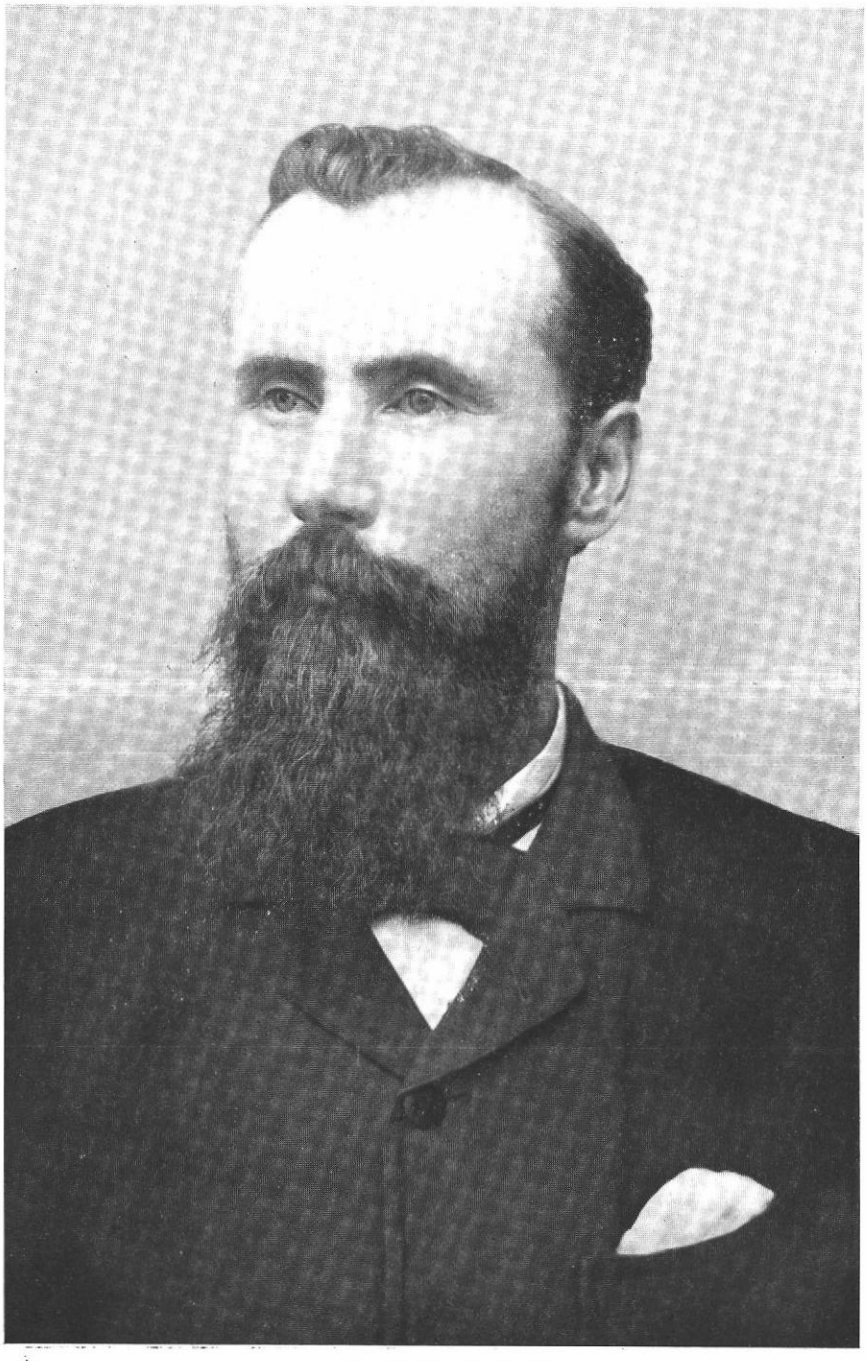
Col. Thos. Rowe, F.R.I.B.A.		President to January, 1899
Hon. Jacob Garrard, M.L.A. (In succession to Col. Rowe, deceased)		President from Jan., 1899
G. A. Mansfield, F.R.I.B.A.		Official Member
John Macpherson		do.
Ald. F. Buckle	City Council	City Member to March, 1898
Ald. Henry Chapman	do.	City Member from March, 1898
Ald. John Taylor	do.	City Member Vice-President
Ald. John Ahearn	Burwood Council	Suburban Member
Ald. David Davis	Woollahra Council	do.

1900-1904

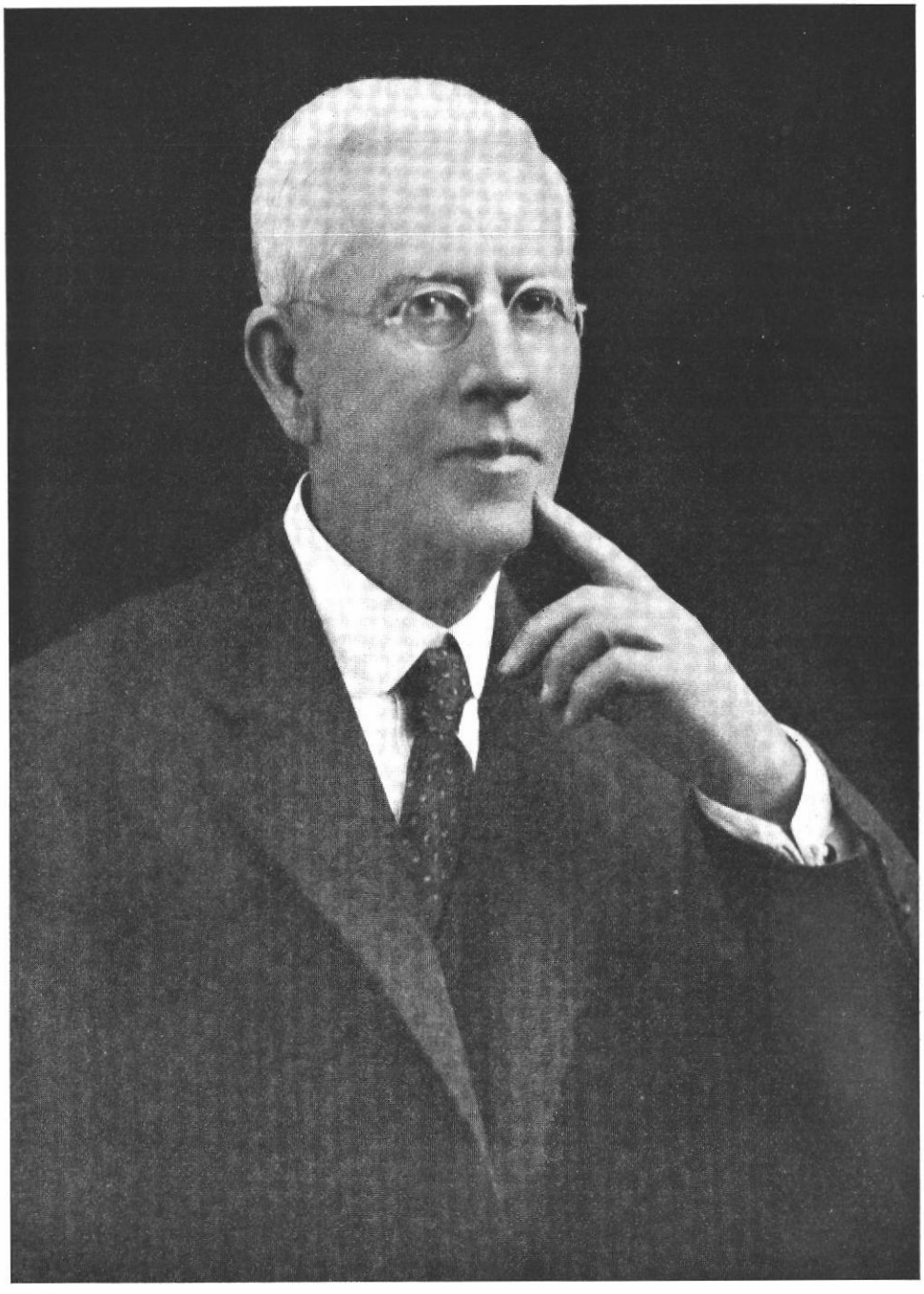
Hon. Jacob Garrard		President
John Macpherson		Official Member
James Ward		do.
Ald. H. Chapman	City Council	City Member to March, 1902
Ald. R. G. Watkins	do.	City Member from March, 1902
Ald. John Taylor	do.	City Member Vice-President
Ald. David Davis	Woollahra Council	Suburban Member to March, 1902
Ald. Thos. Henley	Drummoyne Council	Suburban Member from March, 1902
Ald. J. G. Griffin	Bexley Council	Suburban Member

1904-1908

T. W. Keele, M.Inst.C.E.		President
John Macpherson		Official Member
L. A. B. Wade, A.M.Inst.C.E.		Official Member to June, 1904



HON. JACOB GARRARD
Third President of the Board (1900-1904).



MR. T. W. KEELE, M.INST.C.E.
Fourth President of the Board (1904-1908).

Hon. Jacob Garrard		Official Member from June, 1904
*Ald. Evan Jones	City Council	City Member
Ald. R. G. Watkins	do.	City Member to Dec., 1905
Ald. R. D. Meagher, M.L.A. (in succession to Ald. R. G. Watkins, dec'd.)	do.	City Member from Jan., 1906
*Ald. J. G. Griffin	Bexley Council	Suburban Member
*Ald. T. Henley, M.L.A.	Drummoyne Council	do.

* Served a term as Vice-President. During this period the practice, which continued until April, 1935, was introduced of electing a new Vice-President every twelve months.

1908-1912

W. J. Millner, A.M.Inst.C.E.		President
John Macpherson		Official Member
*Hon. Jacob Garrard		do.
Ald. Evan Jones	City Council	City Member
Ald. R. D. Meagher, M.L.A.	do.	City Member to March, 1910
Ald. T. H. Barlow	do.	City Member from March, 1910
*Ald. J. G. Griffin	Bexley Council	Suburban Member
*Ald. T. Henley, M.L.A.	Drummoyne Council	do.

1912-1916

W. J. Millner, A.M.Inst.C.E.		President
John Macpherson		Official Member to March, 1914
J. McNeill		Official Member from March, 1914
*Ald. J. Leitch	Redfern Council	Official Member
*Ald. Evan Jones	City Council	City Member
Ald. T. H. Barlow	do.	do.
*Ald. J. G. Griffin	Bexley Council	Suburban Member
*Ald. T. Henley, M.L.A.	Drummoyne Council	do.

* Served term as Vice-President.

1916-1920

W. J. Millner, A.M.Inst.C.E.		President
*Ald. J. Leitch	Redfern Council	Official Member
J. McNeill		Official Member to June, 1916
*Hon. F. H. Bryant, M.L.C. (In succession to J. McNeill, deceased)		Official Member from June, 1916

*Ald. Evan Jones	City Council	City Member to May, 1917
Ald. W. O'Connor (In succession to Ald. Evan Jones, dec'd.)	do.	City Member from June, 1917
Ald. T. H. Barlow	City Council	City Member to March, 1918
Ald. W. P. Fitzgerald	do.	City Member from March, 1918
†Ald. T. Henley, C.B.E., M.L.A.	Drummoyne Council	Suburban Member
*Ald. J. G. Griffin	Bexley Council	do.

* Served term as Vice-President.

† On War Service leave as Hon. Commissioner, War Chest Fund—November, 1915, to October, 1919.

1920-1925

W. J. Millner A.M.Inst.C.E.		President
Hon. F. H. Bryant, M.L.C.		Official Member
*J. Leitch		do.
*Ald. W. O'Connor	City Council	City Member to March, 1922
Ald. A. McElhone (In succession to Ald. W. O'Connor, appointed Commissioner, Sydney Harbour Trust)	do.	City Member from March, 1922
Ald. W. P. Fitzgerald	City Council	City Member to March, 1922
*Ald. D. Gilpin	do.	City Member from March, 1922
Ald. E. Glasgow (In succession to Ald. Gilpin, whose seat became vacant on his ceasing to be a member of the City Council)	do.	City Member from March, 1924
Ald. J. G. Griffin	Bexley Council	Suburban Member to August, 1923
T. W. Keele, M.Inst.C.E.		Suburban Member from Oct., 1923
*Ald. Sir Thos. Henley, K.B.E., M.L.A.	Drummoyne Council	Suburban Member to May, 1922
*Ald. B. Richards (In succession to Sir Thomas Henley, who, having accepted office as Minister for Public Works, resigned his seat on the Board)	Marrickville Council	Suburban Member from June, 1922

* Served term as Vice-President.

In December, 1924, the 1880 and 1888 Acts were repealed and replaced by a new Act (No. 50) reconstituting the Board under the title of "The Metropolitan Water, Sewerage and Drainage Board," endowing it with extended powers as a constructing authority and giving it complete control of its own finances. Its area of operations was defined as the City of Sydney, the Islands in Sydney Harbour, any catchment area and certain areas enumerated in the second schedule of the Act. There was also power to include additional areas by Gazette proclamation. It provided that the new Board should consist of a President appointed by the Governor for a period of five years, and seventeen elected members representing nine constituencies into which the municipalities and shires in the Board's area of operations were grouped according to a schedule to the Act. Eight of these constituencies elected two members and the ninth one member. Nine of the elected members who secured the higher number of votes held office for four years and the remaining eight held office for two years. All elections thereafter were for four year terms. The Mayors and Aldermen of the municipalities and the Presidents and Councillors of the shire councils in the Board's area of operations comprised those entitled to vote at the elections. The qualifications of a candidate for office as Board member remained the same as under the former Act, as also the Board's right to elect one of its members as Vice-President.

The personnel of the various Boards under this Act, which commenced to function on 31st March, 1925, was as follows:—

1925-1929

T. B. Cooper		President
Members.		
Ald. J. R. English[a]	To Dec., 1927	1st Constituency, City of Sydney
W. Stuart[a]	From Feb., 1928	
Ald. F. Green[a]	To Dec., 1927	
A. E. Rudder[a]	From Feb., 1928	
T. W. Keele, M.Inst.C.E.[b]	To May, 1927	2nd Constituency— Paddington, Randwick, Redfern, Vaucluse, Waverley, Woollahra
Ald. A. H. Moverly	From Aug., 1927	
Ald. E. S. Sautelle		
Ald. J. E. Galloway		3rd Constituency— Alexandria, Botany, Darlington, Erskineville, Marrickville, Mascot, Newtown, Petersham, St. Peters, Waterloo
Ald. B. Richards		

*Ald. W. T. Tate Ald. R. E. Reid	4th Constituency— Bankstown, Bexley, Canterbury, Kogarah Hurstville, Rockdale
Ald. T. O. Correy D. Gilpin	5th Constituency— Annandale, Ashfield, Burwood, Concord, Enfield, Glebe, Homebush, Leichhardt, Lidcombe, Strathfield
*Ald Sir Thos. Henley, K.B.E., M.L.A. Ald. R. C. Forsyth	6th Constituency— Balmain, Drummoyne, Hunter's Hill, Lane Cove, Manly, Mosman, North Sydney, Warringah Shire
*Clr. P. A. James Ald. J. Henley	7th Constituency— Dundas, Eastwood, Ermington and Rydalmere, Hornsby Shire, Ku-ring-gai Shire, Ryde, Willoughby
G. C. Scouller, L.S. Ald. T. Cheetham	8th Constituency— Auburn, Baulkham Hills Shire, Blacktown Shire, Cabramatta and Canley Vale, Castlereagh, Colo Shire, Fairfield, Granville, Nepean Shire, Parramatta, Holroyd, Richmond, St. Marys
Ald. N. McL. Smith[c] Ald. W. A. Lang, From July, 1928	9th Constituency— Bulli Shire, Camden, Campbelltown, Central Illawarra, North Illawarra, Ingleburn, Liverpool, Sutherland Shire, Wollondilly Shire, Wollongong

* Served term as Vice-President.

[a] Following legislation in November, 1927, for the establishment of a Civic Commission to take over the management of the City from the City Council, other legislation was passed in December, 1927, rendering vacant on 3rd January, 1928, the seats held by the two representatives (Ald. J. R. English and Ald. F. Green) who had been elected by the City Council, and in February, 1928, the Civic Commission, by virtue of the power vested in it, appointed Messrs W. Stuart and A. E. Rudder in their places.

[b] Died May, 1927.

[c] Died 25th May, 1928.

MR. W. J. MILLNER, A.M.INST.C.E.
Fifth President of the Board (1908-1925).

MR. T. B. COOPER
Sixth President of the Board (1925-1935).

1929-1933

T. B. Cooper			President
Members.			
W. Stuart[a]	To July, 1930	1st Constituency	
Ald. A. McElhone[b]	From Aug., 1930, to Mar., 1931	1st Constituency	
A. E. Rudder[a]	To July, 1930	1st Constituency	
Ald. A. L. Parker	From Aug., 1930	1st Constituency	
Ald. G. A. Parkes	From Mar., 1931	1st Constituency	
Ald. A. H. Moverly, M.L.A.		2nd	,,
*Ald. E. S. Sautelle		2nd	,,
Ald. J. E. Galloway		3rd	,,
Ald. B. Richards[c]	To May, 1932	3rd	,,
Ald. A. E. Harris	From July, 1932	3rd	,,
*Ald. W. T. Tate		4th	,,
Ald. R. E. Reid		4th	,,
Ald. T. O. Correy[d]	To Feb., 1930	5th	,,
*Ald. S. A. Lloyd, A.F.I.A., M.L.A.	From Apr., 1930	5th	,,
*D. Gilpin[b]	To Mar., 1931	5th	,,
Ald. A. N. Campbell, A.M.I.E.Aust.	From Apr., 1931	5th	,,
Ald. Sir Thos. Henley, K.B.E., M.L.A.		6th	,,
Ald. R. C. Forsyth[b]	To Mar., 1931	6th	,,
Ald. S. F. R. Hardy, L.S.	From Apr., 1931	6th	,,
Clr. P. A. James		7th	,,
Ald. J. Henley		7th	,,
G. C. Scouller, L.S.		8th	,,
Ald. T. Cheetham		8th	,,
Ald. W. A. Lang		9th	,,

* Served term as Vice-President.

[a] Appointed by Civic Commission—Resigned July, 1930, following election of new City Council.

[b] Vacated seat—term expired.

[c] Died May, 1932.

[d] Died February, 1930.

1933-1935

T. B. Cooper			President
Members.			
*Ald. G. A. Parkes Ald. E. P. Tressider		1st Constituency	
*Ald. A. H. Moverly M.L.A. Ald. E. S. Sautelle		2nd	„
Ald. J. E. Galloway Ald. A. E. Harris		3rd	„
W. T. Tate Ald. R. E. Reid		4th	„
Ald. S. A. Lloyd, A.F.I.A., M.L.A. Ald. A. N. Campbell, A.M.I.E.Aust.		5th	„
Ald. S. F. R. Hardy, L.S. Ald. J. H. Cross		6th	„
Clr. P. A. James[a] Ald. J. Henley	To Dec., 1934	7th	„
Ald. T. Cheetham Ald. G. E. Maunder		8th	„
Clr. E. S. Shaw		9th	„

[a] Died 8th December, 1934.

* Served term as Vice-President. Ald. A. H. Moverly as Vice-President acted in the President's place during the latter's absence abroad from 27th April, 1933, to 21st December, 1933.

The large Board of eighteen, with its dual representation of eight constituencies, proved an unwieldy administrative unit, and in 1935, an Act (No. 4) was passed reducing the Board to seven persons, consisting of a President and Vice-President (both appointed by the Governor) and five elected members. As before, the area controlled by the Board was divided into constituencies, each constituency electing one member, the electors being the Aldermen and Councillors of the various municipal and shire councils, and the persons eligible for election being those qualified to act as Aldermen or Councillors. The term of office of the President and Vice-President was five years, and

BOARD AS CONSTITUTED BY ACT NO. 50 OF 1924 ASSEMBLED AT ITS FINAL MEETING, APRIL 29TH, 1935.

From left, seated: Ald. T. Cheetham, Ald. R. E. Reid, Ald. J. H. Cross, T. B. Cooper (President), Clr. E. S. Shaw, Ald. J. E. Galloway, Ald. A. E. Harris.

„ standing: Ald. S. A. Lloyd, A.F.I.A., M.L.A.; Ald. G. E. Maunder, Ald. E. S. Sautelle, Ald. E. P. Tressider, Ald. S. F. R. Hardy, L.S.; F. J. Henry (Secretary), Ald. G. A. Parkes, Ald. A. N. Campbell, A.M.I.E. (Aust.); Ald. A H. Moverly, M.L.A.; E. G. Audet (Chief Clerk).

BOARD AS RE-CONSTITUTED UNDER ACT NO. 4 OF 1935 ASSEMBLED AT ITS INITIAL MEETING, 30TH APRIL, 1935.

From left, seated: Ald. A. N. Campbell, A.M.I.E. (Aust.); T. D. Kelly, C.M.G., F.I.C.A, (Vice-President); T. H. Upton, O.B.E., M.Sc., M.C.E. M.Inst.C.E., M.I.E, (Aust.) (President); F. J. Henry (Secretary), Ald. A. H. Moverly, M.L.A.

„ standing: E. G. Audet (Chief Clerk), Ald. R. C. Forsyth, Ald. R. S. Goddard, Ald. G. E. Maunder.

of the elected members four years. All the elected members retire at the one time. The new Board took office on 30th April, 1935, and consisted of:—

T. H. Upton, O.B.E., M.Sc., M.C.E., M.Inst.C.E., M.I.E.Aust. President
T. D. Kelly, C.M.G., F.I.C.A. Vice-President

Members.

Ald. R. S. Goddard	1st Constituency— Alexandria, Annandale, Balmain, Darlington, Erskineville, Glebe, Marrickville, Newtown, Paddington, Redfern, St. Peters, Sydney, Waterloo.
Ald. A. H. Moverly, M.L.A.	2nd Constituency— Bexley, Botany, Canterbury, Hurstville, Kogarah, Mascot, Randwick, Rockdale, Vaucluse, Waverley, Woollahra.
Ald. A. N. Campbell, A.M.I.E.Aust.	3rd Constituency— Ashfield, Auburn, Bankstown, Burwood, Concord, Drummoyne, Enfield, Granville, Homebush, Leichhardt, Lidcombe, Petersham, Strathfield.
Ald. R. C. Forsyth	4th Constituency— Dundas, Eastwood, Hornsby, Hunter's Hill, Ku-ring-gai, Lane Cove, Manly, Mosman, North Sydney, Ryde, Warringah Shire, Willoughby.
Ald. G. E. Maunder	5th Constituency— Baulkham Hills Shire, Blacktown Shire, Bulli Shire, Cabramatta and Canley Vale, Camden, Campbelltown, Castlereagh, Central Illawarra Shire, Colo Shire, Ermington and Rydalmere, Fairfield, Holroyd, Ingleburn, Liverpool, Nepean Shire, North Illawarra, Parramatta, Richmond, St. Marys, Sutherland Shire, Wollondilly Shire, Wollongong.

Act 43 Vic. No. 32 of 1880 provided for regulations to be made by the Governor for the purpose of carrying out the elections of members of the Board, and this included the appointment of the returning officer and any other officials necessary to assist him. The elections from

1888 to 1925 were carried out under the supervision of officials of the Public Works Department, but on the reconstitution of the Board in the latter year, the conduct of future elections was entrusted to the Board's Secretary as returning officer. A system of election by personal ballot operated up till 1922, but with the suburban constituencies spread over such a wide area as had by that time developed, and with only a limited number of polling places provided, it was found that not more than 50 per cent of the Aldermen recorded their votes. Postal voting was therefore substituted in 1922, and this resulted in an average of 97 per cent of the votes being recorded in subsequent elections. This system prevailed until 1935, when election by personal ballot was reverted to, but with a polling place at each municipal or shire council chambers in the Board's area of operations. This arrangement has proved satisfactory from the point of view of the percentage of votes recorded, but is expensive, involving as it does the employment of a large staff of deputy returning officers and assistants.

Remuneration of Members of the Board.

Act 43 Vic. No. 32 of 1880 provided that the President should receive such salary as the Governor may determine and as may be voted by Parliament, and that every other member of the Board should be entitled to receive, as remuneration for his services, a sum not exceeding £150 per annum, to be paid to him in the form of a fee (subsequently fixed at £3) for each meeting of the Board, at which he shall have been present up to the time of the termination thereof, and of such amount as the Governor may appoint. The office of an elected member of the Board was not to be deemed an office of profit under the Crown. When the Sydney sewerage was transferred to the control of the Board in 1889, Act 53 Vic. No. 16, by which this was implemented, increased the yearly sum payable to members of the Board to £250. The fee per meeting then became £5 up to the annual limit stated.

Thirty-five years later, when the personnel of the Board was increased to 17 in addition to the President, this was reduced to £200 per annum, from which it was increased, in 1935, to £260 per annum, when the Board was reduced in numbers to a total of seven. The fees now payable to the Vice-President and elected members are £5 per meeting up to the annual limit.

Under the Acts governing the Board from 1888 to 30th March, 1925, the President was not debarred from engaging in any profession, trade, business or other employment outside the duties of that office, but with the growth of the institution and its ramifications, the office gradually developed into a full time one. When, therefore, the Board was reconstituted in March, 1925, with greater responsibilities (constructional and financial), the Act which brought this about stipu-

MR. T. H. UPTON, O.B.E., M.Sc., M.C.E., M.Inst.C.E., M.I.E.Aust.
Seventh President of the Board.

lated that the person appointed as President should not during his term of office engage in any trade, business, or in any employment other than the performance of his duties under the Act. The President is paid an annual salary at such rate as is determined from time to time by the Governor.

Board Meetings—Procedure.

The Board for some few months after its inception met twice a week (Tuesdays and Fridays at 3 p.m.) in order to overcome the large amount of work connected with the inauguration of the new institution. After it had settled into its stride, the meetings were held weekly, on Tuesday afternoons at 3 p.m., special meetings being held whenever business of an urgent nature required to be dealt with. For many years past, however, the meetings have been held on Wednesday mornings at 11 a.m., unless the intervention of public holidays has required a change of the day of meeting. The business so transacted generally occupies about two hours. Special meetings or extended meetings in the afternoon are on occasion necessary, when an unusual amount of business requires attention or matters of importance involve prolonged consideration and discussion. Periodical inspection of the works under the Board's control are made as is deemed necessary.

The Board conducts its meetings according to the standard rules of debate. Until 1925, the adoption of any by-laws governing its discussions proved unnecessary, but with the larger Board of President and seventeen elected members, this became essential. The code of by-laws drawn up by that Board, with minor amendments, still pertains, although the necessity for them with a smaller Board has largely disappeared. From the outset, representatives of the Press have been admitted to the Board meetings to enable them to report any matters discussed in open Board which might be considered to be of public interest. Matters of internal concern relating to staff, finance, etc., or in connection with which the Board's position might be prejudiced by premature publicity, are dealt with in committee of the whole. In due course reports are made in open Board on aspects of any matter so dealt with which are of importance from the public standpoint.

The Boards which functioned from 1888 to April, 1935, were empowered to elect one of their number to be Vice-President, and the member so elected presided at the Board meetings in the absence of the President, and was vested with the same powers and duties as the President while so acting. The Act of 1935, however, provided for the appointment of the Vice-President by the Governor, but gave the Board the power to elect a temporary Chairman in the absence of both the President and Vice-President. A quorum of the original Board of seven members (1888-1925) consisted of three members, of whom the President

or Vice-President needed to be one. The Board of eighteen members (1925-1935) required ten members (of whom the President or Vice-President should be one) to be in attendance to form a quorum. In the case of the present Board of seven members, any four members form a quorum. All questions arising at any meeting are decided by a majority of the votes of the members present, the President, or in his absence the Vice-President, having a casting vote in addition to a deliberative vote.

Board's Offices and Depots.

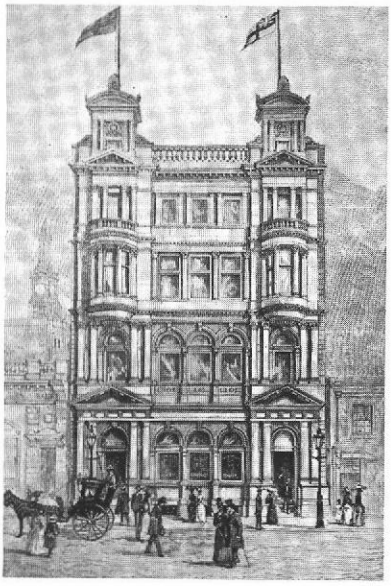
The office premises occupied by the Board immediately after it came into existence in April, 1888, were situated at the western extremity of Circular Quay adjacent to the Sailors' Home. They were part of a building owned by the New South Wales Government (Defence Department) which had just been vacated by the Australian Steam Navigation Company due to its merging into the Australian United Steam Navigation Company. The remaining portion of the building was occupied by the Ordnance Stores. It still stands to-day as the property of the Commonwealth Government (Defence Department).

The location of this office was inconvenient for all concerned, and in August, 1888, a sub-committee of the Board which had been deputed to report on suitable sites for the erection of office premises, recommended that application be made to the Government for portion of the land at the corner of Market and Castlereagh Streets, adjoining what was then the Girls' High School and now occupied by the establishment of David Jones, Ltd. This was not acceded to, but the Government Land Valuer was instructed to furnish a report on eligible sites. As a result of his report, which was submitted to the Board in August, 1889, it was decided to recommend the acquisition of the present site at the corner of Pitt and Wilmot Streets. This was approved by the Government, and in March, 1891, the block, which had a frontage to Pitt Street of 72-ft. and a depth of about 83-ft., was resumed at a cost of £23,280—about £323 per foot of frontage to Pitt Street. The land boom was at its height at the time. The requisite offices were erected thereon by Mr. P. Hill, at a cost of £28,900, and the Board entered into occupation in May, 1893.

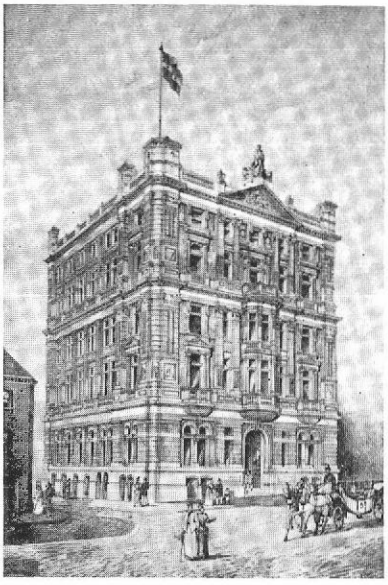
In the meantime, a shift had been made (in January, 1890) from the original offices to temporary quarters in a new building (No. 289) on the western side of Pitt Street, near Park Street, which had just been erected for the Australian Mutual Investment and Building Society. This building has since been merged into the premises of F. J. Palmer and Sons Ltd.

In 1910, an additional frontage of 87-ft. to Pitt Street was acquired at a cost of £14,500 (approximately £167 per foot or about half the

1888-1889
Circular Quay.



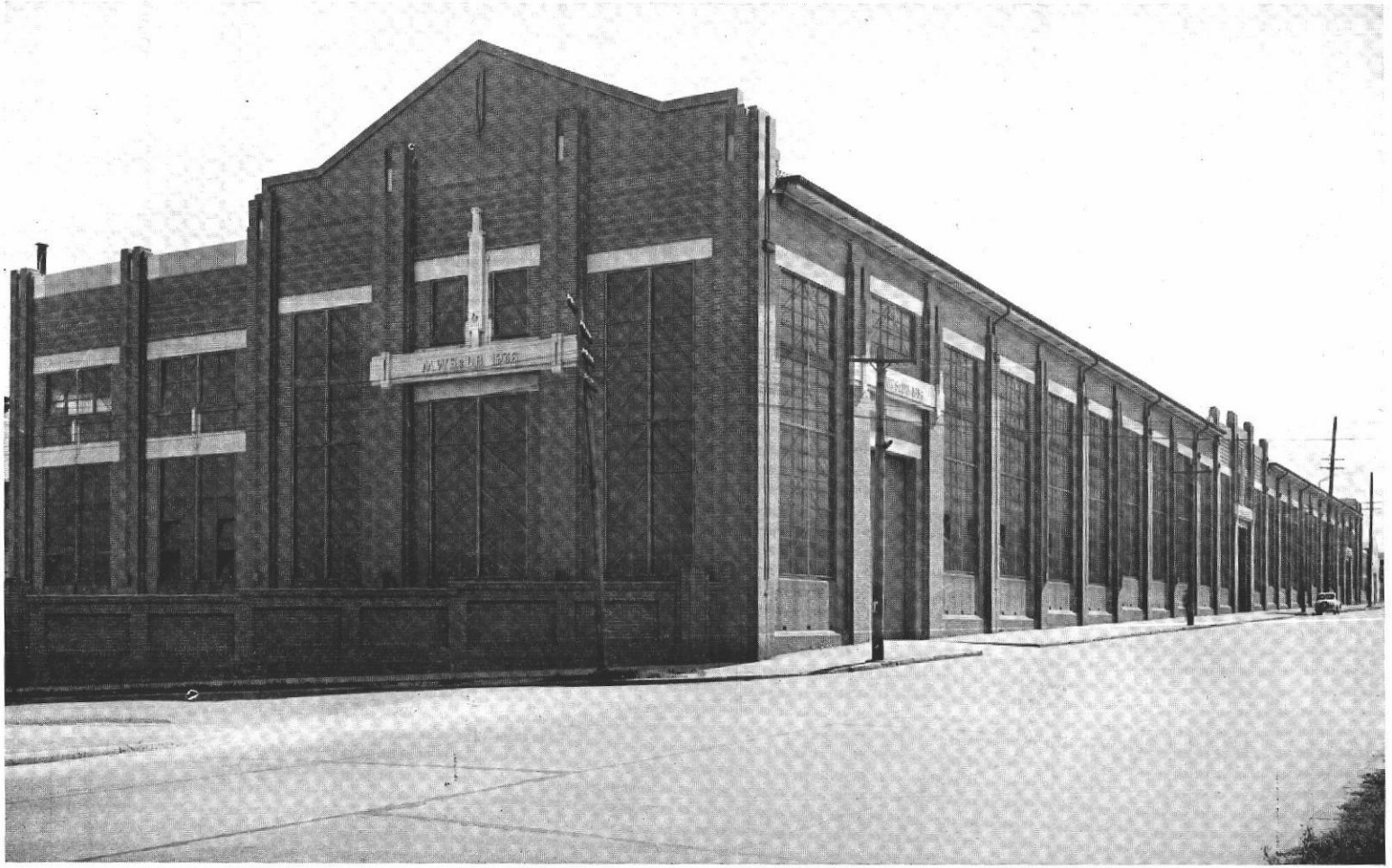
1890-1893
289 Pitt Street.



1893-1918
341 Pitt Street.

1918-1939
341 Pitt Street, extended.

BOARD'S HEAD OFFICES.



WATERLOO DEPOT AND CENTRAL WORKSHOPS.

price per foot of the original site), and extensions in harmony with the original building were completed in 1918.

Additional land and buildings at the rear of the extended office were purchased in 1929 and 1936, and that portion of Stewart Lane separating the Board's properties was resumed, thus providing a block, approximating 160-ft. square, suitable for comprehensive planning in such a way as would provide not only for present needs but future development. The old offices and the other buildings purchased, which had not been built with a view to extension or the construction of additional storeys, did not lend themselves to this principle, and as a serious state of staff congestion had been in existence over several years, it was decided in 1936 to clear the site and to erect a new building consisting of a basement, ground floor, mezzanine, and six upper floors, in accordance with modern requirements. This is now in course of erection. The columns and foundations of the building have been designed so that, as required, additional storeys can be added up to the full height (150-ft.) allowed by the City Council's regulations. Meanwhile, since October, 1937, the Board has been occupying rented premises at the corner of Reservoir and Mary Streets, Surry Hills.

Except in two cases, viz. at Parramatta and Wollongong, the Board has not found it necessary or advantageous to set up branch offices for the conduct of the administrative section of its business. It has, however, sought to meet the convenience of local people by supplementing the postal facilities for the payment of rates in two ways:—

(i) by constituting the Banks in certain of the more distant centres such as Liverpool, Richmond, Camden and Campbelltown, etc. as agents to receive payment of rates on its behalf, and

(ii) by periodical attendance at suburban council chambers, on appointed dates of which the public are fully notified, of officers of the Board to receive payment of rates, etc.

These facilities have existed from the earliest years of the Board's control of the water supply and sewerage systems. In connection with construction and maintenance, the Board has, to an increasing extent, with the expansion of its operations, found it necessary to decentralise the technical staff by establishing district engineers' offices and maintenance depots at a large number of centres from which these operations are carried out, subject, of course, to central control and direction.

The Parramatta office was established, following the transfer to the Board of the Parramatta water supply in 1916 (see Chapter XIII), in rented premises adjacent to the Town Hall. This was to meet the convenience of local ratepayers, plumbers and builders, who had been accustomed under the old regime to transact all their business relating to the water supply and sewerage matters at the local Town Hall. Its activities

were not, however, confined to these but were extended to residents of the adjacent shires and municipalities having business with the Board. In the early years, the operations of this office were limited to the receipt of rates and the issue of meters, and builders', plumbers' and drainers' permits. With the growth of business and the completion of the Northern Suburbs Ocean Outfall Sewer to Parramatta, enabling the sewerage reticulation of Lidcombe, Auburn, Granville etc., to be commenced, larger premises were necessary. In 1924, therefore, the Board acquired a suitable site adjoining the fire station in Church Street, Parramatta, and erected thereon a branch office providing accommodation not only for the clerical staff handling the revenue side of the Board's operations, but also for the district engineer and his technical staff engaged in construction operations in Parramatta and surrounding districts. The office was completed and opened for business in October, 1927.

Although the Board took over the management of Wollongong water supply as agents for the Minister for Public Works in January, 1903, it was not until 1916 when, by virtue of Act No. 13 of that year, the works became vested in the Board, that a branch office was established there. Prior to this, the local turncock, or water service operator as he is now designated, attended to the service of rate notices and accounts, while the local branch of the Commercial Banking Company of Sydney, Ltd., received payment of rates, etc. on the Board's behalf, and remitted the collections monthly to the Board's head office. From 1916 to 1923, the Board's local officers occupied rented accommodation in the School of Arts building in Crown Street, Wollongong. In the latter year the Board erected a branch office on a site in the same street acquired seven years previously. With the commencement of the Wollongong Sewerage Scheme in 1927, it became necessary to locate a district engineer and technical staff in that town, and in 1930 on the retirement of the water service inspector, the former took over the control of the whole of the construction and maintenance (water and sewerage) in the South Coast districts. A separate office and a depot were erected in 1929 for the district engineer on additional land acquired at the rear of the original office premises. Further land acquired in 1935 and 1938 brings the total area now occupied to approximately one acre.

The depots initially used by the Board were those taken over from the City Council at Newtown Road, Crown Street Reservoir Reserve and Park Road. The first ceased to be used in a few years, and the property was then leased to the Institute for the Deaf and Dumb, and in 1903 vested in that body. The Crown Street (Surry Hills) Depot was first used as an office for the Comptroller of Stores and his staff, and to accommodate stores, meter workshops also being erected on the site. In 1894 the Comptroller of Stores and staff were brought to Head Office and the space thus vacated devoted to the carrying out of machinery and plant repairs. The depot continued to function in this manner

until 1936, by which time the Board's activities had so developed as to render the re-organisation of its whole system of depots imperative. As a result, all operations other than the meter workshops and the testing and inspection of water and sewerage fittings were removed elsewhere, and the Crown Street establishment now operates solely as a testing organisation. Certain other plant for the testing of materials has been added in conformity with this ideal, while further remodelling has yet to be carried out.

The Park Road Depot was utilised for many years solely for the storage of pipes, but in 1916 the machinery and plant workshops were transferred to it from Crown Street owing to congestion at the latter place. Coincident with the general depot reorganisation in 1936, comprehensive remodelling of Park Road took place, and it now constitutes the Board's main store.

A further depot was established in 1891 at Balmain Road, Leichhardt, following the construction of the main pipe lines from Potts Hill to Crown Street by the Public Works Department and the vesting in the Board of certain land which had been acquired by that Department in connection with these works. It was originally used for the storage of large pipes, valves and castings. Additional areas totalling about ¾ths of an acre were acquired in 1912 and 1936, making a total area of 3 acres. The depot was then remodelled under the 1936 rearrangement, and has since functioned as the headquarters of the water and sewerage maintenance operations, suitable buildings having been provided for the storage of plant and fittings and to accommodate the staff which deals with these matters. There is also a garage block for motor vehicles and mobile cranes.

The latest depot is at Waterloo, at the corner of Bourke and McEvoy Streets, where a large workshop was erected in 1936 and to which the repair machinery from other depots was then transferred. It contains mechanical, electrical, carpenters and blacksmiths shops and a plant testing equipment, and is devoted almost exclusively to the repair and servicing of the Board's maintenance and construction plant. Certain storage accommodation is also available.

Staff:

The principal officers of the Board have been:—

Secretary:

May, 1888, to June, 1895	Reginald Bloxsome
July, 1895, to June, 1917	Major-General William Holmes, C.M.G., D.S.O., V.D.
July, 1917, to June, 1931	T. J. Roseby
June, 1931, to June, 1937	F. J. Henry, A.S.I.A.
From 1st July, 1937	W. O. C. Day, D.E.C.

Mr Reginald Bloxsome resigned on 30th June, 1895.

Major-General Holmes served as a Captain and later as a Major in the South African War. With the rank of Colonel, he commanded the expedition which, soon after the outbreak of the Great War (1914-1918), was despatched from Australia and took possession of German New Guinea. Returning early in 1915, he left in May of that year, with the rank of Brigadier-General in command of the 5th Infantry Brigade, and later was promoted on active service to the rank of Major-General. He was killed in action on 2nd July, 1917.

Mr T. J. Roseby and Mr F. J. Henry retired on, or shortly after, reaching the age limit of 65 on 25th June, 1931, and 30th June, 1937, respectively.

Chief Engineer:

Board Engineer	1888-1890—J. Trevor Jones, C.E.
Engineer for Water Supply ..	1890-1893—J. Trevor Jones, C.E.
Engineer for Sewerage	1890-1893—J. M. Smail, M.Inst.C.E.

Mr J. Trevor Jones, who was Engineer for Water Supply under the City Council prior to his transfer to the Board's service, was compelled to resign his position owing to failing eyesight at the end of 1893, when Mr J. M. Smail was appointed Chief Engineer in charge of both Water Supply and Sewerage.

Chief Engineer .. 1894 to June, 1920—J. M. Smail, M.Inst.C.E.
(Title altered to Engineer-in-Chief in 1901.)
Chief Engineer .. 1920 to October, 1927—J. G. S. Purvis, M.Inst.C.E.
Chief Engineer .. 1928 to June, 1933—G. Haskins, M.Inst.C.E.

Mr J. M. Smail died in June, 1920; Mr J. G. S. Purvis in October, 1927; and Mr G. Haskins resigned in June, 1933.

Chief Engineer Water Supply } 1933 to Decr., 1935 S. T. Farnsworth, B.Sc. (Eng.), Lond., Assoc.M.Inst.C.E.
Chief Engineer Sewerage } 1933 to Decr., 1935 J. N. C. MacTaggart, M.E., M.Inst.C.E.

Mr MacTaggart retired after reaching the age limit on 19th May, 1936.

Engineer-in-Chief From Dec., 1935 S. T. Farnsworth, B.Sc. (Eng.), Lond., M.Inst.C.E.

Accountant:

1888-1919—Melbourne Green, F.I.I.A.
1919-1931—C. H. Campbell, A.F.I.A.
1931-1935—R. Byrne, A.F.I.A.
From April, 1935—I. S. Pring, A.I.C.A.

Messrs Green and Byrne retired after reaching the age limit of 65, while Mr Campbell retired voluntarily at the age of 60.

Assessor:

From 1888 to 1898—H. J. Beaumont
From 1898 to 1905—T. J. Roseby

As from 30th June, 1905, a re-organisation scheme took effect under which all business relating to the collection of the Board's revenue was transferred from the Accountant to the Assessor, and the title of the latter was altered to "Assessor and Receiver."

Assessor and Receiver:

From 1905 to July, 1917—T. J. Roseby
From July, 1917, to June, 1931—F. J. Henry, A.S.I.A.
From June, 1931, to June, 1937—W. O. C. Day, D.E.C.
From July, 1937—H. T. Weldon.

The total number of officers and employees in the service of the Board at 30th June, 1938, was 6,788, made up as follows:—

Professional Officers	534
Administrative and Clerical Officers	604
General Division Officers	614
Wages Division Employees—"A" Class	851
"B" Class	4,185
	6,788

These figures do not include men paid out of Unemployment Relief moneys, of whom there were 456 at 30th June, 1938.

CHAPTER II

RATING, FINANCE AND GUARANTEES

Rating.

When, in April, 1888, the Board took over the control and management of the Sydney water supply from the City Council and began to function, the latter body had levied the water rate for the half-year ending 30th June, 1888. The Council ceased to receive payment of these rates on 14th May of that year, the public being notified through the press and by notices exhibited at the Town Hall that on and from 1st June, 1888, payment of outstanding rates would be received by the newly-constituted Board of Water Supply and Sewerage. This interval was necessary to enable the list of outstanding rates to be transcribed into the Board's registers. The overdue rates and charges amounted approximately to £45,000, and embraced chiefly unpaid rates for 1887 and the first half of 1888, their large volume being due to the fact that since the introduction of Nepean water into the mains, the Council had been unable to take summary procedure against delinquent ratepayers, owing to the Nepean works not being vested in it.

The Board of Water Supply and Sewerage assumed far greater financial responsibilities than the City Council had borne in connection with the Sydney water supply, since although the works and assets handed over by the Council were valued at the time at £465,625 17s. 3d., (this value was written down in 1904 to £248,647 4s. 2d.), by virtue of a provision in the Sydney Corporation Act of 1879, the debt of the Council to the Government for the loan money advanced to it in connection with the construction of the Botany water supply and the earlier schemes, amounting to £243,261, had been written off, and the only capital liability of the Council at the time of transfer of the works to the Board was a debenture debt of £85,000. The general body of taxpayers of New South Wales were therefore at that time carrying the greater portion of the burden of debt in respect of the water supply works operated by the Council, and the charges for water made by it were much below those required to give an adequate return on the whole capital sum expended. It was the responsibility of the Board

to adjust this position, and to collect sufficient revenue from those receiving the service to meet working expenses and interest on the amount expended by the Government on the Upper Nepean scheme which had just been completed.

The method of rating by the Council for water supply at the time of transfer was crude and inequitable, being based on a flat rate per room (3s. 6d.) irrespective of the size of the room or the building or its value. Even this had been reduced from 5s. per room shortly before the Board took over. The explanation lies doubtless in the fact that there was little or no debt on the works which the Council was operating, as it is significant that at the same time, the rating for municipal services in the City, including the sewerage service, and in other incorporated areas, was at a rate in the £ of annual value. The Act under which the Board was to operate stipulated that it should levy its rates on assessed annual values (defined as nine-tenths of the rental value), not exceeding the valuations under this head recorded in the municipal assessment books. It also provided that the rates should not exceed 5 per cent (1s. 0d. in the £) for each of the water and sewerage services. Rating on annual values for the water and sewerage services was then, and is now, the system most generally adopted by water and sewerage authorities throughout the British Empire and elsewhere. At various times since 1906, when rating on unimproved land values for municipal services became general in New South Wales, there have been advocates of a change to this basis of rating for the water and sewerage services of the metropolitan area, but the legislature has never seen fit to clothe the Board with power to make such a change, and successive Boards have never been prepared to advocate it. Investigation has always demonstrated that rating on the annual value of the land and improvements more equitably places the burden in relation to the probable use of the services. The Act of 1924 contained a provision, when introduced into Parliament, giving the Board the option of rating on either unimproved or assessed annual values. This provision was, however, amended, and the Act, as finally passed, empowered the Board to rate wholly on annual values or alternatively to adopt a dual system of rating, partly on unimproved and partly on annual values, rating on the former basis being subject to limitations prescribed in the Act. The Board has not found it feasible to introduce this rather complicated alternative, which would greatly increase office routine and be confusing to ratepayers.

When the Board took over control of the Sydney water supply, the expenditure on the Nepean scheme stood at approximately £2,500,000, including £423,657 interest accrued during construction, and

provision for interest on this amount as well as working expenses had to be taken into account in striking the initial rates. These were struck on a sliding scale as under:—

On assessed annual values of	£20 and under	10s. per annum (minimum rate)
„	£21 to £300	6d. in the £
„	£301 to £700	5d. „
„	£701 to £1000	4d. „
„	£1001 to £4000	3d. „
„	Over £4000	2d. „

and yielded an annual revenue of slightly over £90,000, or nearly double that yielded by the City Council's rate of 3s. 6d. per room. This increase, together with the change of incidence of the charge, not surprisingly brought forth a crop of protests at the outset, but it was not long before the dual need was recognized and the ratepayers settled down to the new system. The sliding scale remained in operation until 1st July, 1904, with an increase from 6d. to 7d. in the maximum rate from 1st January, 1894.

On 30th September, 1889, Act 53 Vic. No. 16 was passed, transferring to the Board the property in and the control and management of all sewerage works constructed by the City Council or any other council in the County of Cumberland. It also provided for the vesting in the Board by Gazette proclamation, as and when completed, of the main sewerage schemes being carried out by the Government to intercept the main portion of the then existing City sewerage system from the Harbour outfalls, and convey the sewage to the sea at Ben Buckler (Bondi), and Botany Sewage Farm. This proclamation was duly published on 18th December, 1889, and it then became the Board's duty to put into action the rating provisions of the Act in respect of the sewerage service. The City Council levied and collected sewerage rates up to 31st December, 1889, and the Redfern Council, which had recently constructed a reticulation system connecting with the Government's main southern sewer, collected rates to 1st February, 1890. The City Council was at the time of transfer levying a sewerage rate of 6d. in the £ on assessed annual values, but the state of the finances of the Sewerage fund indicated that this was inadequate. The Board had, as in the case of the water supply, to assume financial responsibility for the added debt in respect of the Governmental expenditure on the main intercepting sewers and branches, which at that time amounted to approximately £1,000,000, in addition to taking over councils' debts for sewerage works amounting to £280,822 (City Council, £253,110, Redfern Council £22,712, Darlington Council £5000). The initial rate struck by the Board as from 1st January, 1890, was 7d. in the £ of assessed annual value.

STORMWATER DRAINAGE RATES

TABLE OF RATES LEVIED WITHIN STORMWATER DRAINAGE AREAS SINCE 1st JULY, 1923.

Drainage Areas	Size of Area	Rate in £ on Assessed Annual Values, year commencing 1st July.													Municipalities and Shires into which each Drainage Area extends
		1st July, 1923, to 30th June, 1926	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	
	Acres	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	
Auburn	138	5	3¼	3	2¾	2¾	2½	2¾	2½	2¼	2¼	2¼	2¼	2¼	Auburn
Balmain Slopes	74	2	1½	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	Balmain
Beattie Street	155	1½	1½	2¼	1½	1¾	1½	1¼	1¼	1¼	1¼	1¼	1¼	1¼	Balmain
Blackwattle Bay	649	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	City, Darlington, Glebe, Newtown, Redfern
Botany (Bay Street)	438	6½	4	3	3¼	2½	2	2¼	2	2	2	2	2	2	Botany
Brickfield Creek	726	4¼	2½	2¼	2	3½	4¼	3½	3	2¾	2¾	2¾	2¾	2¾	Baulkham Hills Shire, Parramatta
Brook Street—Rated from 14/2/1930	151	—	—	—	—	½	½	¼	½	½	½	½	½	½	North Sydney, Willoughby
Callan Park	60	1	¾	1¾	1¾	1½	1¾	1¼	1	1	1	1	1	1	Balmain
Careening Cove [a]	127	—	—	—	—	1¼	1	1	1	1	1	1	1	1	North Sydney
Chatswood-Willoughby	525	2½	1¾	3½	4	2	1¾	2	1¾	1¾	1¾	1¾	1¾	1¾	Willoughby
Clay Cliff Creek	544	3½	2¾	5¾	4¾	4¾	4½	4¾	4	3	3	3	3 [c]	3 [c]	Granville, Parramatta, Holroyd
Doody Street—Rated from 6/3/1931	480	—	—	—	—	—	5	5¾	5	3½	3½	3½	3½	3½	Alexandria, Mascot, Waterloo
Double Bay	700	½	1	¾	¾	¾	¾	½	¼	¼	¼	¼ [c]	¼ [c]	¼ [c]	Randwick, Waverley, Woollahra
Druitt and Washington Streets	6	½	½	¼	¼	¼	¼	¼	½	½	½	½	½	½	City
Duck Creek—Rated from 3/5/1929	284	—	—	—	—	5½	5¼	5¾	5¼	3¾	3¾	3¾	— [b]	— [b]	Holroyd
Easton Park	141	1¼	1	1	1	1	1	¾	¾	¾	¾	¾	¾	¾	Balmain, Leichhardt
Euroka Creek	56	1	¾	¾	¾	½	½	½	¾	¾	¾	¾	¾	¾	North Sydney
Hawthorne Canal	1121	1¾	1¼	1¾	1¾	1½	1¼	1½	1	1	1	1	1	1	Ashfield, Leichhardt, Petersham
Henley Park—Rated from 23/5/1930	442	—	—	—	—	3¾	3¾	3¼	3	2¾	2¾	2¾ [c]	2¾ [c]	2¾ [c]	Canterbury, Enfield
Homebush Creek	335	3¼	2½	2½	2¼	2	2	2¼	2½	2¼	2¼	2¼	2¼	2¼	Burwood, Strathfield
Hurstville	—	7	6	4¾	4¼	—	—	—	—	—	—	—	—	—	Hurstville (not now rated, was slopwater drain area, now sewered)
Iron Cove Creek and Iron Cove Creek Extended	1655	2¼	2	2½	2¾	2¼	2¼	2¾	2½	2¼	2¼	2¼	2¼	2¼	Ashfield, Burwood, Canterbury, Drummoyne, Enfield
Johnston's Creek	1120	¾	½	1¼	1½	1	1	1	¾	¾	¾	¾	¾	¾	City, Annandale, Glebe, Marrickville, Newtown, Petersham
Liverpool	86	6¼	7	6¼	5½	4¼	3¾	4¼	3¾	3	3	3	3	3	Liverpool
Manly	62	1	1	½	½	¼	1	1	½	½	½	½	½	½	Manly
Marrickville Valley—Rated from 22/10/1926	1920	—	1	¾	¾	1¾ [e]	—	—	¼	¼	¼	¼	¼	¼	Alexandria, Marrickville, Newtown, Petersham, St. Peters
Mosman	369	½	½	½	½	½	½	½	½	½	½	½	½	½	Mosman, North Sydney
Neutral Bay [a]	289	1	¾	1¼	1	½	¾	¾	¼	¼	¼	¼	¼	¼	North Sydney
Orissa Street	118	4½	3¾	2¼	3	2¾	2½	2¾	— [b]	— [b]	— [b]	— [b]	— [b]	— [b]	Canterbury
Penkivil Street — Rated from 1/7/1924	106	1¾	1¾	1½	1½	1¼	1¼	1¼	1½	1½	1½	— [b]	— [b]	— [b]	Waverley
Rose Bay — Not rated prior to 11/3/1927	826	—	½	½	¼	½	2¼	"A" 6¼ [d]	6¾	5¼	5¼	— [b]	— [b]	— [b]	
								"B" ¾ [d]	¾	¾	¾	¾	¾	¾	Waverley, Woollahra
Rushcutters Bay	600	½	¼	½	½	¼	½	½	¼	¼	¼	¼	¼	¼	City, Paddington, Woollahra
Shea's Creek	2087	1½	1¼	1½	2	1½	2	2½	2¾	2½	2½	2½	2½	2½	City, Alexandria, Erskineville, Newtown, Randwick, Redfern, Waterloo
Waverley-Woollahra (Norwich Rd.)—Rated from 9/7/1926	168	—	4¼	2¾	2¼	2¼	2	2¼	3¼	3	3	3 [c]	3 [c]	3 [c]	Waverley, Woollahra
White's Creek	—	½	1	1½	2	1½	1¼	1¼	¾	¾	¾	¾	¾	¾	Leichhardt, Annandale, Petersham
Willoughby Falls	—	1	¾	¾	¾	½	½	½	¾	¾	¾	¾	¾	¾	North Sydney
Kippax Lake—Not rated	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

[a] Neutral Bay and Careening Cove were rated as one drain up to 30/6/29.

[b] Contribution equal to total yield of proposed rate made to Board by Local Council, no rate was therefore necessary.

[c] No drainage rates levied in these years within the Canterbury portion of Henley Park Area or the Waverley portion of Double Bay and Norwich Road Areas or the Holroyd Portion of Clay Cliff Creek Area, contributions equal to the total yields of the rates in these portions of the areas named being paid by the respective Councils under the power given in this respect in the Board's Amendment Act No. 4 of 1935.

[d] Zone "A" Waverley. Zone "B" Woollahra.

[e] Interest on Public Works Department Expenditure provided for from 1/7/29 subsequently remitted by Government and treated as expenditure on National Works. No rate levied until 1/7/32 as set off against overcharge in 1929/30.

Up till 1st January, 1890, the Board did not levy rates on vacant allotments to which the water and sewerage services were available, but from that date to 1st July, 1904, the water rate levied on vacant lands varied from 2d. to 4d. in the £ compared with 6d. to 8d. in the £ on house properties, and the sewerage rate from 3d. to 4d. in the £ compared with 7d. to 1s. in the £ on house properties. In 1898, following the completion by the Government of the Western Suburbs main sewers and the North Sydney main sewerage works, and two years later, the Willoughby-Chatswood system, the Board levied a higher sewerage rate (1s. in the £) in these new areas than that (7d. in the £) applying in the City and Eastern and Southern Suburbs draining to the original schemes (Bondi and Botany Sewage Farm), the reason being that ratable values in the districts served by these later schemes were lower in relation to cost than in the City and older suburbs. A sewerage rate of 1s. in the £ was also levied in respect of the City and Double Bay low level areas, to drain which, pumping stations and rising mains were necessary, and in connection with which annual pumping expenses were involved. In 1904, however, a doubt arose as to the Board's power to levy these differential rates in the metropolitan area, and from 1st July, 1904, except in country districts or areas remote from the Metropolis, uniform water and sewerage rates have been struck. Rates on vacant land, which had hitherto been on a lower basis, were also brought up to the same level from that date. Special rates continued to be struck on account of both water supply and sewerage schemes serving country districts or areas remote from the Metropolis until 30th June, 1937, when with a view to assisting rural settlement and industry, the Government undertook to pay thenceforth annually to the Board amounts equal to the yield of any special rates that the Board would otherwise levy.

The Act of 1924 provided that the water, sewerage and drainage rates should be levied annually, instead of half-yearly as they had been since 1888, and this change was given effect to from 1st July, 1925. For some few years prior to this, an increasing number of ratepayers had availed themselves of the option of paying a full year's rates in the first half-year (July-December), for the reason that it spread the outgoings for all rates more evenly over the twelve months, the Board's rating year dating from 1st July, and that of the municipal councils (which outside the City all rated on a yearly basis) from 1st January, income taxes being also payable between January and June. From the administrative point of view, the change was most welcome, owing to the increasing difficulty and expense, with the huge growth of business, involved in going through the whole of the routine associated with the levy and collection of the rates twice a year. At that time, the number of properties rated exceeded 320,000 and was increasing at the rate of

several thousands each year. The institution of annual rating also enabled the Board to give more extended terms to ratepayers who had difficulty in meeting their commitments for rates. Very few objections were raised to the change, and annual rating for the water and sewerage services is to-day as firmly established as annual rating by the Local Government bodies.

Instead of making its own valuations for rating purposes, which, as before stated, were required by the 1880 Act not to exceed the municipal assessments, the Board at the outset adopted the method of transcribing the valuations from the municipal assessment books into its own books. This system was continued until the Valuation of Land Act became law in 1916, and constituted a valuing authority (the Valuer-General) for all rating bodies, including municipalities and shires. The Valuer-General began to furnish valuation rolls to the Board in 1918, but it was not until 1927 that such rolls were available for the whole of the municipalities and shires (apart from the City) embraced in the Board's area of operations.

The statement shown opposite, furnishes information at the end of each triennial period, 1888 to 1938, as to assessment rates levied and the revenue of yield therefrom. It also indicates, by the increase shown in the number of properties served, the extent of development that has taken place in the water and sewerage systems. It will be noted that both water and sewerage rates have remained unchanged since 1st July, 1934. On that date and also on 1st July, 1933, reductions were made under an arrangement with the Government, whereby the saving to the Board resulting from the reduction of interest granted by the Government on the Board's indebtedness to the State from those dates (see later) was applied to reducing the water and sewerage rates each by 1¼d. in the £ over the two years. From 1st July, 1936, and for the ensuing five years, under a further arrangement with the Government, the Board has undertaken not to increase the rates. This has been made possible by legislation (Act No. 54) passed in December, 1935, providing for progressive remissions of the Board's capital indebtedness to the State, aggregating £11,450,000 over the five-year period, coincidentally with the borrowing and expenditure by the Board of £15,000,000 of new loan moneys and the carrying out of a renewals programme at the rate of £250,000 p.a. The rates, therefore, since 1st July, 1935, are substantially below what they would have needed to be were it not for Governmental asssistance. This is particularly the case on the sewerage side, as will be appreciated from the fact that returns prepared show that many of the new districts will not be capable of returning sufficient revenue, at current rates and valuations, to meet annual charges (interest and sinking fund) on the capital cost of local reticulation, even when all vacant

SCHEDULE SHOWING WATER AND SEWERAGE RATES CHARGED, REVENUE DERIVED THEREFROM, AND NUMBER OF HOUSES SERVED, 1st JANUARY, 1888, TO 30th JUNE, 1938

Year Ending	WATER SUPPLY			SEWERAGE		
	Rate	Yield £	Number of houses served	Rate	Yield £	Number of houses served
30th Dec., 1888	6d. in £ up to £300 5d. in £—£301 to £700	90,582	Approx. 61,718			
30th „ 1890	4d. in £—£701 to £ to £1000. 3d. in £—1000 to £4000	103,306	71,501	7d. in the £	65,138	22,765
30th „ 1893	2d. in £ over £4000 2d. in £ on vacant land from 1890	118,728	81,288	3d. in the £ on vacant land	89,392	36,062
30th June, 1896	7d. in £ up to £300 with sliding scale as above. 4d. in £ on vacant land	133,020	85,059	7d. in the £ 4d. in the £ on vacant land	85,167	44,462
30th June, 1899	do. do.	126,754	92,370	7d. in £ and 4d. in £ on vacant land, City, Eastern and Southern Suburbs 1/- in £ Western Suburbs and North Sydney	97,006	58,720
30th „ 1902	do. do.	136,344	101,966	1/- in £ Double Bay and City Low Level System	130,557	82,644
30th June, 1905†	8d. in the £	186,327	112,343	11d. in the £	211,495	85,958
30th June, 1908	7d. in the £	179,887	124,083	10d. in the £	214,379	96,384
30th June, 1911	6d. in the £	176,130	139,237	9½d. in the £	232,148	108,012
30th June, 1914	6d. in the £	230,369	166,112	9½d. in the £	294,513	118,643
30th June, 1917	6½d. in the £	296,260	193,643	10d. in the £	379,990	136,409
30th June, 1920	7½d. in the £	433,703	212,046	11d. in the £	494,474	145,304
30th June, 1923	9d. in the £	714,993	239,528	10½d. in the £	631,562	159,390
30th June, 1926	8½d. in the £	960,009	268,558	9d. in the £	763,921	176,338
30th June, 1929	8¾d. in the £	1,244,450	299,401	9d. in the £	984,049	192,574
30th June, 1932*	9d. in the £	1,379,978	311,246	8d. in the £	972,805	208,287
30th June, 1935	9¼d. in the £	1,114,477	322,480	8¾d. in the £	858,834	221,701
30th June, 1938	9¼d. in the £	1,218,330	341,948	8¾d. in the £	977,947	253,967

† Commencement of uniform rate.

* Rates were increased from 1st July, 1932, from 9d. to 10½d. in the £ Water, and from 8d. to 10d. in the £ Sewerage, to compensate for fall of over 20 per cent in ratable values. They were, however, each reduced by 1d. in the £ from 1st July, 1933, and by a further ¼d. in the £ from 1st July, 1934, as a result of the Government reducing the rate of interest on the Board's loan indebtedness to the State.

allotments have been built upon, assuming the character of future buildings to be the same as those already existing. In such circumstances, no contribution towards the annual charges in respect of the capital cost of the trunk and outfall mains with which they are linked, or their maintenance, can be looked for from these extensions of the system.

With regard to drainage rates, it is necessary to explain that these were not levied until Act 57 Vic. No. 12 was passed in 1894 vesting in the Board stormwater drains which had been constructed by the Government in the City and suburbs. This Act also authorised the proclamation by the Board of a drainage area in respect of each drain and the levying of rates up to a limit of 3 per cent on the assessed annual value of all lands within the boundaries of the proclaimed areas, with the proviso that when any land became liable for sewerage rates, the drainage rate levied thereon should cease. This resulted in a diminishing drainage revenue as the sewerage system was extended. In 1916 an amendment of the Act removed this proviso and the cost of all stormwater drains serving sewered areas also became chargeable to the Board's Capital Account. For some years, however, the Board did not consider it expedient to exercise the power which it thus had to levy drainage rate on all properties within an area whether rated for sewerage or not, but adopted a uniform drainage rate of ½d. in the £ (increased from 1st July, 1922, to 1d. in the £) on properties ratable for sewerage while continuing to charge drainage rates varying from 7d. to 1d. in the £ on unsewered properties. On 1st July, 1923, the differentiation between sewered and unsewered properties was abandoned, and since that date, one drainage rate has applied throughout each proclaimed drainage area. The statement opposite page 25 gives particulars of the rates so levied.

An amendment of the Board's Act was made in 1935 to meet cases where, on account of the magnitude of the drainage scheme and the low ratable value of the lands drained, a drainage rate if levied in the restricted area of the drainage basin as required by the Act would be oppressive. Some councils desired in such cases to spread the charge over the whole municipality by paying the Board the equivalent of the yield of the drainage rate out of their (the councils') general rate income. Hence the amendment referred to, which empowers the Board and a council to enter into such an arrangement, and during its effective duration the Board's drainage rate remains inoperative. Three councils have so far taken advantage of this arrangement in respect of eight stormwater drainage areas which are wholly or partly within the boundaries of their municipalities.

The following table sets out the rates charged from time to time in respect of the main water supply and sewerage schemes serving country districts or areas remote from the Metropolis up to the date (30th June, 1937) of the elimination of all special rates:—

	WATER					SEWERAGE	
Year	Camden and part of Nepean Shire	Ingleburn and parts of Campbelltown, Liverpool and Nepean Shire	Richmond and Colo Shire	Sutherland-Cronulla	Wollongong and South Coast Districts	Hornsby	Wollongong
	Rate in £	Rate in £	Rate in £	Rate in £	Rate in £	Rate in £	Rate in £
1893-1898			1s. 0d.				
1899-1903	1s. 0d.*		1s. 0d.				
1903-1904	1s. 0d.		1s. 0d.		1s. 0d.		
1904-31/12/06	8d.		1s. 0d.		1s. 0d.		
1/1/07-1908	7d.		1s. 0d.		1s. 0d.		
1908-1914	6d.		1s. 0d.		1s. 0d.		
1914-1916	6d.		1s. 0d.		1s. 0d.	1s. 0d.	
1916-1917	6d.		1s. 0d.		10d.	1s. 0d.	
1917-1918	6½d.	1s. 0d.	1s. 0d.		1s. 0d.	1s. 0d.	
1918-1920	7½d.	1s. 0d.	1s. 0d.		1s. 0d.	1s. 0d.	
1920-1924	9d.	1s. 0d.	1s. 0d.		1s. 0d.	1s. 0d.	
1924-1925	7½d.	1s. 0d.	1s. 0d.		1s. 0d.	1s. 0d.	
1925-1926	8½d.	1s. 0d.	1s. 6d.		1s. 0d.	1s. 0d.	
1926-1929	1s. 6d.	1s. 0d.	1s. 6d.		1s. 0d.	1s. 0d.	
1929-1930	1s. 6d.	1s. 0d.	1s. 6d.		1s. 0d.	1s. 0d.	1s. 6d.
1930-1931	1s. 4½d.	11d.	1s. 4½d.		11d.	11d.	1s. 6d.
1931-1932	1s. 6d.	1s. 0d.	1s. 6d.	2s. 0d.†	1s. 0d.	1s. 0d.	1s. 6d.
1932-1933	1s. 6d.	1s. 2d.	1s. 10d.	2s. 0d.	1s. 1½d.	1s. 0d.	1s. 6d.
1933-1935	1s. 5d.	1s. 0d.	1s. 6d.	1s. 6d.	1s. 0d.	11d.	1s. 5d.
1935-1937	1s. 4d.	1s. 0d.	1s. 6d.	1s. 6d.	11d.	11d.	1s. 5d.

* From October, 1899.

† From 1925 to 11th December, 1931, Metropolitan rate charged.

PAYMENT FOR WATER BY MEASURE

The assessment rating covers the supply of water for domestic and sewerage purposes. Where water is required for other purposes, such as garden watering, car washing, or commercial enterprises, special charges are made, calculated on the actual volume of water used as measured by meter, or fixed at a flat rate where the expense of meters and meter reading in relation to the use would be disproportionate. The following are the charges that have been levied from time to time for water by measure. It will be noted that, excepting in one instance (Wollongong and South Coast district) and excluding rebates, the charges are now, and have been for a long time, uniform, irrespective of the quantity of water used. This is due to the fact that the Board has consistently aimed to keep them as low as possible for all users. Consequently there is no margin for tapering rates for the larger consumers.

Year	METROPOLITAN AREA	Richmond and Colo Shire	Upper Canal Above Prospect Reservoir	Lower Canal Prospect Reservoir to Pipe Head	COUNTRY DISTRICTS		Wollongong and South Coast‡	Sutherland-Cronulla
					Ingleburn and parts of Campbelltown, Liverpool, and Nepean Shire	Camden and part of Nepean Shire		
	per 1,000 galls.	per 1,000 gs.	per 1,000 gs.	per 1,000 gs.	per 1,000 gs.	per 1,000 gs.	per 1,000 gs.	per 1,000 gs.
1888-1891	1s. 6d.							
1892	1s. 0d. up to 20 ms. 9d. thereafter							
1893	do.	1s. 6d.						
1894-1903	do.	do.	3d.	6d.				
1903-1909	do.	do.	do.	do.			1s. 6d. up to 100,000 gs., 1s. 0d. thereafter	
1909-1916	11d. up to 10 ms. 10d. 10 to 20 ms. 9d. thereafter	do.	do.	do.			do.	
1916-1918	do.	do.	do.	do.	1s. 6d.		1s. 6d. up to 10 ms. 10d. over 10 to 20 9d. thereafter	
1918-1920	1s. 0d. up to 10 ms. 11d. 10 to 20 ms. 10d. thereafter	do.	do.	do.	do.		do.	
1920-1922	1s. 1d.*	do.	do.	do.	do.		do.	
1922-1926	1s. 0d.	do.	do.	do.	do.		do.	
1926-1928	do.	do.	do.	do.	do.	1s. 6d.	do.	
1928-1930	1s. 3d.	do.	do.	do.	do.	do.	do.	
1930-1931	1s. 2d.	do.	do.	do.	do.	do.	do.	
1931-1932	do.	1s. 3d.	do.	do.	1s. 3d.	1s. 3d.	do.	3s. 0d.†
1932-1933	1s. 4d.	do.	do.	do.	do.	do.	do.	Rated properties—2s. 6d. to limit of assessment allowance; 2s. thereafter. Properties not rated—3s.
1933-1939	1s. 2d.	do.	do.	do.	do.	do.	do.	1s. 2d.

* Sliding scale discontinued.

† Prior to 10-12-1931, the Metropolitan rate applied to Sutherland-Cronulla.

‡ For Electrolytic Refining & Smelting Co. of Aust. Ltd.
- Up to 1 million, 9d. per 1000 gallons.
- Over 1 to 3 million, 8d. per 1000 gallons.
- Over 3 to 5 million, 7d. per 1000 gallons.
- Over 5 to 14 million, 6d. per 1000 gallons.
- Consumption over 14 million at district rates.

From 1st July, 1921, to 30th June, 1923, a minimum charge of 5s. per annum was made in respect of every property requiring a meter in addition to the rental of the instrument.

Since 1st July, 1932, a rebate of 2d. per 1000 gallons has been allowed over the metropolitan area proper for any consumption in one year in excess of the quantity used in the previous year. Since 1st July, 1935, a rebate to the same extent on all water consumed in any year irrespective of what was used in the previous twelve months, has been given to all market gardens, nurseries, and premises used for cut flower growing (as specially registered by the Assessor and Receiver) over the whole area of the Board's operations, i.e. inclusive of country districts, and this was extended to include poultry farms running not less than 150 head of stock, and orchards, as from 1st July, 1936.

In the case of Wollongong and the South Coast towns, the existence of a comparatively high rate per 1000 gallons has made possible the retention of a sliding scale affecting the very large consumers, and this has undoubtedly proved of assistance to the important industrial undertakings located in those districts. A special rate and sliding scale has been retained with regard to water consumed by meter by the Electrolytic Refining and Smelting Co. of Aust. Limited, an agreement on those lines having been made with the Minister for Public Works prior to the Board taking over the Wollongong and South Coast water supply.

The value of the water consumed in excess of assessment ratings, and the number of meters in use from time to time, is shown in the following table:—

Year	Value of excess water consumption including meter rentals	Number of Meters in Operation		
		Hired from Board	Privately owned	Total
Calendar year	£	Hiring out of meters commenced 1st March, 1894		
1890	38,383		4,758	4,758
Financial year				
1895-1896 ..	41,552	1,575	4,559	6,134
1900-1901 ..	60,936	6,230	3,704	9,934
1905-1906 ..	70,928	15,130	2,972	18,102
1910-1911 ..	109,456	26,790	1,815	28,605
1915-1916 ..	168,126	43,763	1,294	45,057
1920-1921 ..	246,413	66,173	1,132	67,305
1925-1926 ..	319,820	98,106	1,098	99,204
1930-1931 ..	342,465	103,113	963	104,076
1935-1936 ..	373,039	111,432	784	112,216
1937-1938 ..	412,030	116,686	786	117,472

In 1927—13,773 non-revenue producing meters were removed from premises where the garden area was not in excess of 1000 sq. ft., and a garden fee of 8s. per annum substituted. During 1934-1935, a further 1360 meters were removed under the same arrangement.

Meters.

Prior to 1894, consumers requiring a meter had to purchase these instruments from merchants importing them, and subject to their passing a satisfactory test by the Board, the meters were permitted to be affixed to the water service pipes. Owing to the multiplicity of types imported, the Board experienced difficulty in keeping a stock of spare parts for repairing them. It was therefore decided to adopt a standard type of meter, and when supplies became available, to require all future consumers through meter to obtain the instruments from the Board, either on hire or by purchase. The type of instrument selected was a turbine meter very similar to that in use at the time by the Hydraulic Department of South Australia. A contract was let for the manufacture of the meters in Australia and from 1st March, 1894, supplies became available. The former types were superseded as they came in for repairs, consumers finding it advantageous to hire meters of the standard type. In 1900, fullway meters for services of 2-inch diameter and over were introduced, with by-pass meters controlled by automatic valves to register small flows.

The design of the meters thus obtained has been improved from time to time, but being of the inferential type, a margin of 5 per cent for variation, fast or slow, has to be recognized. The Board has recently (1937) taken steps gradually to supersede the inferential with a positive type of meter, a satisfactory instrument of the latter character being now obtainable.

The rentals charged for meters from time to time are as under:—

Year	Size of Service Pipe					
	½ in.	¾ in.	1 in.	1½ in.	1½ in.	2 in. (ord.)
1888-1894	No charge.					
1/3/1894-1897	7/-	9/-	11/-	13/-	15/-	
1897-1899	5/6	7/-	8/6	10/-	12/-	16/6
1899-1908	4/6	6/-	7/-	8/6	10/-	16/6
1908-1909	Rents not charged.					
1909-1923	(Not in use)	6/-	7/-	8/6	10/-	£1/11/9*
1923-1939	do.	8/-	9/-	10/6	12/-	£1/15/9*

* Includes valve and by-pass.

A comparatively small number of meters 3-inch to 10-inch are also rented at varying rates.

Garden Fees.

A system of allowing the watering of small gardens by hose on payment of a special fee instead of requiring the fixing of a meter, was adopted very early in the history of the Board, viz., from 1st January, 1889, and has applied ever since except for the period 1901-1911, when the need to conserve the water supply made it necessary to abolish it temporarily. This suspension commenced during the severe drought of 1901-1902, when Prospect was the only storage reservoir in existence and had become so depleted that Sydney was threatened with a complete failure of the supply, and continued until Cataract Dam had been completed and was filled to capacity.

Although the system was re-introduced in 1911, it was always recognised that in the regrettable necessity during prolonged droughts for restrictions to be applied to the use of water, garden watering should be the first use to be curtailed. However, restrictions have not been imposed on more than seven occasions during just over fifty years of the Board's existence, and then only for short periods.

The following table gives particulars of garden fees and shows the varying conditions applicable thereto:—

1/1/1889 to 30/6/1897 ..	10s. per annum for every 750 sq. ft. or part thereof.
1/7/1897 to 30/6/1898 ..	10s. per annum for 1000 sq. ft. or part thereof, and 2s. 6d. for every additional 250 sq. ft. or part thereof.
1/7/1898 to 31/12/1901 ..	10s. per annum for gardens which do not exceed 1000 sq. ft. in area.
1/1/1902 to 30/6/1911 ..	Abolished.
1/7/1911 to 30/6/1922 ..	2s. 6d. per annum for 250 sq. ft. or part thereof, up to 2000 sq. ft. (For use of hose held in hand only.)
1/7/1922 to 30/6/1923 ..	5s. per annum for 500 sq. ft. or part thereof and 2s. 6d. for every additional 250 sq. ft. to 2000 sq. ft. (For use of hose held in hand only.)
1/7/1923 to 30/6/1927 ..	10s. per annum for areas not exceeding 1000 sq. ft. taken as one-sixth of the total area of the allotment. (For use of hose held in hand only.)
1/7/1927 to 30/6/1938 ..	8s. per annum for areas not exceeding 1000 sq. ft. taken as one-sixth of the total area of the allotment. (No restrictions as to unattended hose or sprinkler.)

Finance.

It has already been explained that until 1925 the Board was, by virtue of the Acts under which it operated, in the same category as a Government department as regards its finances. It had no statutory responsibility in the way of a Capital Debt, and its financial transactions were not segregated in the Public Accounts of the State in the form of a separate Profit and Loss Account. Its revenue was paid into the Consolidated Revenue Fund and it expended on construction and working expenses only such sums as were annually voted to it by Parliament. Its annual estimates of expenditure on proposed works had to be submitted to the Minister for Works, and were subject to revision as necessitated by the exigencies of Governmental finance. The enforced postponement of urgent works from time to time by reason of this pruning of the Board's estimates militated against the systems being kept abreast of requirements, and involved the Board in much adverse criticism when the peak summer demands disclosed weaknesses in the water supply system. This disability was removed by Act No. 50 of 1924, which provided for:—

(i) Its Capital Indebtedness to the State to be ascertained, gazetted and charged to it,

(ii) The regular payment to the State Treasurer of interest and sinking fund contributions on the debt, with power to the Treasurer to put in a receiver in case of default,

(iii) The raising by the Board of loans and the arranging by it of temporary accommodation by bank overdraft, subject to prior Executive Council approval,

(iv) The provision of a Sinking Fund on the debt to the State (on the basis fixed by legislation) and the Board's own loan flotations (on a basis approved by the Executive Council); and

(v) The responsibility for the raising of annual revenues sufficient to enable the Board to meet its financial obligations.

That Act therefore marks the birth of the Board's real financial responsibility as an independent statutory authority under the Crown.

The Board had from its inception adopted an accountancy system which enabled it to compile annual revenue accounts and balance sheets, but without officially certified figures regarding the cost of the main works constructed by the Government and vested in it from time to time, or as to the rate of interest chargeable on the loan expenditure. The results which these early annual statements exhibited could therefore only be regarded as approximate. To rectify this, on 17th May, 1904, a committee under the presidency of the Auditor-General, of which the Under-Secretary for Public Works, the President of the Board, the Chief Accountant of the Treasury, the Accountant, Public Works Department,

and the Board's Secretary and Accountant, were members, commenced an investigation of the expenditure on metropolitan water, sewerage and drainage works, with a view to arriving at the amount which should be regarded as the capital debt of the Board. The Government of the day did not give this committee any official standing and statutory effect was never given to its findings. However, the figures it arrived at (submitted in a report dated 3rd October, 1905) as representing the capital debt of the Board on 30th June, 1904, were adopted by the Auditor-General and the Board as the foundation on which the Board's capital account was built up in subsequent years by adding the yearly expenditure after agreement had been reached as to the correct amount. A recast of the Board's financial statements from 1888 to 1904 based on the result of the committee's investigation proved that over that period of years the Board had at least levied an adequate revenue to meet interest and working expenses.

From 1st July, 1906, a separate statement of the Board's annual financial results was published in the Auditor-General's annual report, and reconciled with the Board's statements published in its annual report. Interest was charged at the average rate for each year notified by the Treasury as applicable to the Public Debt of the State. However, as before stated, the Board, prior to the Act of 1924, had no real responsibility to the Government to account for any deficit in its accounts nor the Government to it to account for any surplus, and its revenue and working expenses were items only in the Consolidated Revenue Account of the State.

Act No. 50 of 1924, which gave the Board financial autonomy, provided for the appointment of a Committee of Review, consisting of:—

The Chairman of the Public Accounts Committee,
The Auditor-General,
The Director of Finance (Under-Secretary, the Treasury),
The Under-Secretary for Public Works,
The President of the Board,

to investigate and report at what sum the Board's total capital indebtedness to the State at the date of commencement (31st March, 1925) of the Act should be fixed. The amount thus fixed, after adoption by Parliament and notification in the Government Gazette, became the officially recognised capital indebtedness to the State of the Board as at that date. The completion of the Committee's report was subject to prolonged delays, arising out of changes in its personnel, particularly the Chairman, brought about by the change of Government or death. It was therefore not until 6th August, 1931, that the completed report was adopted by Parliament and the capital debt at 31st March, 1925, determined at £23,576,702.

The statement opposite, which was submitted to the Committee of Review, indicated that from 1888 to 30th March, 1925, there had been paid into the Consolidated Revenue Fund the sum of £418,880 in excess of what had been paid out of that Fund for working expenses and interest on loan expenditure for water and sewerage works. The new Board sought to have this amount made available to it as the nucleus of a renewal fund, but the committee decided it had no power to deal with the question and the Treasury officials were not prepared to admit that any such surplus existed if an apportionment of discounts and other expenses connected with the flotation of Government loans were taken into account.

Its construction programme being no longer restricted by the limits of Parliamentary votes from the available loan funds of the State, the reconstituted Board embarked on extensive construction operations designed to catch up the leeway of the past as rapidly as possible and meet urgent requirements for amplification and extension of the services. It was able to make arrangements with the Government for adequate advances by the Treasury from which to finance its construction programmes during the period 1925-1928 and the sum of £6,495,000 was so borrowed. On the termination of this arrangement in July, 1928, the Board made its first independent flotation of a loan. During the first five years of its existence, the new Board had an average capital expenditure of £2,796,000 compared with an average of £1,297,000 similar expenditure by its predecessor over the preceding five years. Notwithstanding this doubling of the annual expenditure on works, such were the needs of the rapidly growing Metropolis that the Board could see ahead of it the necessity for at least ten years of a sustained attack on the problem of bringing the water supply and sewerage systems up to the proper stage of development. With the onset of the economic depression in the latter part of 1930, it was, however, compelled, owing to the difficulty of raising finance, almost to cease construction operations during 1931-1932, except for certain works carried out as unemployment relief works with funds provided by the State Government (chiefly on a basis of half loan and half grant), and later by the Commonwealth Government. At the end of 1932, the condition of the loan market enabled the Board to resume flotations on a limited scale and to supplement the relief works with a construction programme under ordinary working conditions. In September, 1933, the Board, at the suggestion of the Government, again embarked upon an extensive programme of works for the relief of metropolitan unemployment involving expenditure of £2,500,000 over a period of two years. Arrangements for the raising of the necessary loan by the Board were made by the Government which undertook responsibility for the interest over a period of

The results achieved under the Act of 1888, i.e., up to 31st March, 1925, are disclosed in the following Statement showing the Surplus or Deficit on Revenue Account each year carried to Surplus Revenue Account, and the Disbursements on Renewals out of Votes from the State Treasurer's Public Works Fund.

Year	Surplus	Deficit	Expenditure from Public Works Fund for Renewals and Improvements	Balance at Credit of Surplus Revenue Account on 30th June in each year
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1888	45,760 8 10	—		
1889	4,880 6 0	—		
1890	16,784 2 2	—		
1891	33,052 5 1	—		
1892	—	296 13 11		
1893	6,209 8 3	—		
1894	—	5,858 1 10		
1895	—	2,811 14 3		
1895-6	—	5,762 8 6		
1896-7	—	3,668 19 9		
1897-8	—	7,687 13 1		
1898-9	—	2,937 9 7		
1899-1900	—	4,362 9 8		
1900-1	—	2,695 5 1		
1901-2	11,335 3 5	—		
1902-3	2,937 14 3	—		
1903-4	3,401 7 5	—		
1904-5	61,289 5 9	—		
1905-6	72,293 2 10	—		
1906-7	46,570 4 0	—		
	£304,513 8 0	£36,080 15 8		
Less	36,080 15 8			
	£268,432 12 4			
Less— Arrears accumulated on churches and charitable institutions to 30th June, 1907, included in above figures— £20,215 14 10				
Sundry furniture, plant, etc., written off to Revenue Account— £8,078 19 4	28,294 14 2			
Balance carried to Surplus Revenue Account at inauguration of Public Works Fund	240,137 18 2	—	6,665 4 2	233,472 14 0
1907-8	29,456 10 1	—	15,022 3 0	247,907 1 1
1908-9	—	4,033 1 11	24,660 8 10	219,213 10 4
1909-10	7,766 10 9	—	75,618 13 1	151,361 8 0
1910-11	3,102 1 1	—	97,224 15 8	57,238 13 5
1911-12	20,011 13 3	—	50,899 8 0	26,350 18 8
1912-13	38,714 19 2	—	16,155 6 0	48,910 11 10
1913-14	41,638 6 5	—	20,500 3 3	70,048 15 0
1914-15	73,081 19 6	—	17,475 11 4	125,655 3 2
1915-16	63,203 9 2	—	15,678 14 2	156,705 11 6
Richmond and Wollongong accumulated deficit	—	16,474 6 8	—	—
1916-17	—	37,577 4 1	19,289 7 4	99,839 0 1
1917-18	—	16,622 2 3	18,790 11 1	64,426 6 9
1918-19	84,188 3 8	—	12,956 5 11	135,658 4 6
1919-20	—	77,792 8 7	18,578 15 11	39,287 0 0
1920-21	79,061 9 11	—	11,911 3 6	106,437 6 5
1921-22	69,277 8 2	—	13,218 2 8	162,496 11 11
1922-23	67,389 2 11	—	16,757 7 3	213,128 7 7
1923-24	179,018 10 9	—	18,020 11 8	374,126 6 8
1924-25 1st July, 1924, to 30th March, 1925	59,920 16 8	—	15,166 4 6	418,880 18 10
	£1,055,968 19 8	152,499 3 6	484,588 17 4	
Less deficit	152,499 3 6			
	903,469 16 2			
Less expenditure on Renewals and Improvements	484,588 17 4			
Credit balance, 31st March, 1925	418,880 18 10			

two years from the date each instalment of the loan was advanced, in order to avoid any necessity for the Board to increase the rates. The heavy fall in ratable values during the depression period would otherwise have necessitated an increase in the rates to meet the additional interest and sinking fund charges.

In October, 1935, the present Board, at the request of the Government, gave consideration to the question of adopting an augmented construction programme for the further relief of unemployment involving a loan expenditure of £3,000,000 per annum for a period of five years. Investigation of the Board's finances showed that, owing to the heavy fall (over 20 per cent) in ratable values since 1930 and the necessity to expend £250,000 per annum for the next five years on renewals, the adoption of the Government's proposal would involve substantial increase in the rating. The Government thereupon suggested the appointment of a committee to draw up a formula by which the Board's Capital Indebtedness to the State might be progressively reduced to enable it to adopt the Government's proposal without the necessity of increasing the rates. The committee appointed to carry out the review consisted of Mr A. E. Barton, F.C.A. (Aust.), Chairman; Mr T. H. Upton, President M.W.S. & D. Board; Mr T. D. Kelly, Vice-President, M.W.S. & D. Board, and Under-Secretary, The Treasury; Alderman A. H. Moverly, M.L.A., Member, M.W.S. & D. Board; Mr E. H. Swift, Under-Secretary for Public Works; and Mr S. A. Giraud, Valuer General. The committee's report provided for adjustment of the Board's Capital Indebtedness to the State by such progressive reductions as its forecast of revenue and expenditure over the five year period indicated would be required to enable the Board to avoid any deficit each year without increasing the rates. Its findings were given effect to by an Act (No. 54) passed in December, 1935, in which the Capital Remissions to be made at the commencement of each of the five years, based on a loan expenditure of £3,000,000 per annum, are set out as under:—

Year	
1936-1937	£5,750,000
1937-1938	1,750,000
1938-1939	1,500,000
1939-1940	1,250,000
1940-1941	1,200,000
Total	£11,450,000

Provision was also made in the Act for adjustments of these amounts of remission according as the expenditure in any year exceeds or is less than £3,000,000. The total remission over the five year period is, however, not to exceed £11,450,000.

Rates of Interest Paid.

The rates of interest charged to the Board by the Treasury on its Capital Indebtedness to the State, have varied as under:—

From 1925 to 30th June, 1933	The average rate applicable to the State Public Debt, varying from 5·17% to 4·37%.
From 1st July, 1933, to 30th June, 1934	4%
From 1st July, 1934	3½%

The interest rates charged on the amount of £5,520,750 advanced to the Board by the Colonial Treasurer between 1925 and 1928 have been:—

Up to 30th June, 1930	5·375%
From 1st July, 1930, to 30th June, 1931	5·5%
From 1st July, 1931, to 31st December, 1932 ..	5%
From 1st January, 1933, to 30th June, 1933 ..	4·5%
From 1st July, 1933, to 30th June, 1934	4%
From 1st July, 1934	3½%

At 30th June, 1938, the debt in respect of the Treasury advances had been reduced to £5,196,000, and an arrangement concluded by which the remainder is to be paid off over 40 years by equal annual instalments of principal and interest.

From 1930 onwards, the Board's finances have felt the strain of the adverse exchange rate which has ruled since the onset of the economic depression, the Board having to meet its proportion of exchange on remittances of interest in respect of the overseas debt of the State and its own American loan. The charges so incurred are as under:—

1930-1931	£160,489
1931-1932	262,492
1932-1933	283,603
1933-1934	160,259
1934-1935	147,874
1935-1936	144,052
1936-1937	108,774
1937-1938	109,077
Total	£1,376,620

Sinking Fund Payments.

As already stated, the Act of 1924 imposed upon the Board the obligation to establish a Sinking Fund in reduction of its Capital Indebtedness to the State and also in respect of every loan raised by it. The Sinking Fund payments to the State were originally fixed by the Act

referred to at 5 per cent of the gross annual revenue of the Board. This was amended by Act No. 10 of 1928 to 5s. per cent per annum. The Sinking Fund established in connection with the Board's own loan flotations is 10s. per cent per annum. The amounts which have been set aside annually under this head are as follows:—

1925-1926	£106,956
1926-1927	113,167
1927-1928	123,014
1928-1929	69,563
1929-1930	86,914
1930-1931	99,555
1931-1932	103,300
1932-1933	109,834
1933-1934	126,880
1934-1935	134,307
1935-1936	141,596
1936-1937	147,549
1937-1938	164,486
Total	£1,527,121

The following is a statement of the financial results achieved by the Board since the granting to it of financial autonomy:—

WATER, SEWERAGE AND DRAINAGE SURPLUS REVENUE ACCOUNT

				Surplus			Deficit		
1924-1925, 31st March to 30th June, 1925 ..	10,188	2	4						
Less Expenditure from Public Works Fund on Renewals	5,055	8	2	5,132	14	2			
1925-1926							93,714	0	3
1926-1927							113,134	11	4
1927-1928				87,656	9	3			
1928-1929				295,395	9	7			
1929-1930				95,254	12	8			
1930-1931							63,279	10	2
1931-1932				1,006	9	3			
1932-1933				115,636	5	9			
1933-1934							46,335	12	9
1934-1935				19,777	12	4			
1935-1936				62,478	10	5			
1936-1937				122,412	13	7			
1937-1938				69,170	11	1			
				873,921	8	1	316,463	14	6

and it was considered that the principle of a revenue return of 5 per cent over the whole of any municipality would not be suitable. Accordingly on 2nd September, 1936, the Board decided not to impose this requirement in connection with any work carried out under the Five Year Programme, thus relieving the councils of the permanent deficiencies in which they would have otherwise been involved in these cases.

Nevertheless many councils experienced difficulty in meeting their obligations under the guarantee bonds and after representations had been made to the Minister for Works and Local Government, the Government decided on 13th April, 1937, to assume as from 1st July, 1936, the responsibility under all guarantees which had been entered into by the councils. The Government also undertook to guarantee the deficiency in respect of any future extensions for which the councils normally would have accepted responsibility, subject to the return not being less than 2½ per cent per annum, and to the reference in the first place to the Minister of any works where large deficiencies were involved.

Under this arrangement the councils are called upon to guarantee only the difference between revenue receivable and 2½ per cent on the cost of the work, the Government being responsible for the payment of the balance of the deficiency.

REFERENCES

Report from the Committee appointed to investigate and report upon the Capital Account of the Water Supply and Sewerage under the jurisdiction of the Metropolitan Water Supply and Sewerage Board. (Printed 1905.)

Report of the Committee appointed to consider and review the amount of the Capital Indebtedness of the Metropolitan Water, Sewerage and Drainage Board. (Committee appointed 1925, report presented 1931.)

Report of the Advisory Committee Appointed to Review the Board's Financial Position in Relation to the Adoption of an Augmented Loan Programme. (Printed 1936.)

The following is a statement of the Loans raised directly by the Board and current as at 30th June, 1938.

Funds	Where Floated and Payable	No.	Date of Flotation	Term of Loan Years	Date of Maturity	Amount	Total	Net Price Received per cent	Rate per cent paid	Interest (Payable Half-yearly) Yearly Amount	Interest (Payable Half-yearly) Total	Sinking Fund Annual Contribution 10/- %
						£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Water ..	Sydney	1-4	July, 1928	19/21	1 Mar. 1 Sept. 1947	500,000 0 0	1,000,000 0 0	100 0 0	5 15 0 less*	22,281 5 0	44,562 10 0	5,000 0 0
Sewerage ..	—	—	—	—	1947	450,000 0 0				20,053 2 6		
Drainage ..	—	—	—	—	1949	50,000 0 0			9/40ths	2,228 2 6		
Water ..	Sydney	5	July, 1929	15	15 Oct., 1944	742,500 0 0	1,485,000 0 0	99 10 0	5 10 0 less*	31,970 11 0	63,941 2 0	7,500 0 0
Sewerage ..	—	—	—	—	—	722,700 0 0				31,118 0 1		
Drainage ..	—	—	—	—	—	19,800 0 0			9/40ths	852 10 11		
Water ..	Melbourne	6	Jan., 1930	20	15 Apr., 1950	637,500 0 0	850,000 0 0	99 10 0	6 5 0 less*	30,878 18 2	41,171 17 6	4,250 0 0
Sewerage ..	—	—	—	—	—	170,000 0 0				8,234 7 6		
Drainage ..	—	—	—	—	—	42,500 0 0			9/40ths	2,058 11 10		
Water ..	New York	7	Apr., 1930	20	1 Apr., 1950	720,949 7 1	1,441,898 14 2	87 5 0	5 10 0	42,381 11 10	84,763 3 7	7,705 14 11
Sewerage ..	—	—	—	—	—	648,854 8 4				38,143 8 7		
Drainage ..	—	—	—	—	—	72,094 18 9				4,238 3 2		
Water ..	Sydney	8	Mar., 1931	20	4 Mar., 1951	50,000 0 0	50,000 0 0	99 10 0	6 5 0 less* 9/40ths	2,421 17 6	2,421 17 6	250 0 0
Water ..	Sydney	16	Aug., 1932	15	21 Sept., 1947	75,000 0 0	100,000 0 0	100 0 0	5 0 0	3,750 0 0	5,000 0 0	500 0 0
Sewerage ..	—	—	—	—	—	20,000 0 0				1,000 0 0		
Drainage ..	—	—	—	—	—	5,000 0 0				250 0 0		
Water ..	Sydney	17	Dec., 1932	15	1 Jan., 1948	780,000 0 0	1,200,000 0 0	98 0 0	4 5 0	33,150 0 0	51,000 0 0	6,000 0 0
Sewerage ..	—	—	—	—	—	396,000 0 0				16,830 0 0		
Drainage ..	—	—	—	—	—	24,000 0 0				1,020 0 0		
Water ..	Sydney	20	May, 1933	15	1 Jan., 1948	300,000 0 0	500,000 0 0	98 0 0	4 5 0	12,750 0 0	21,250 0 0	2,500 0 0
Sewerage ..	—	—	—	—	—	200,000 0 0				8,500 0 0		
Water ..	—	20	May, 1933	20	1 Jan., 1953	300,000 0 0	500,000 0 0	97 10 0	4 5 0	12,750 0 0	21,250 0 0	2,500 0 0
Sewerage ..	—	—	—	—	—	200,000 0 0				8,500 0 0		
Water ..	Sydney	22	Nov., 1933	23	1 Nov., 1956	960,000 0 0	2,500,000 0 0	100 0 0	4 0 0	38,400 0 0	100,000 0 0	12,500 0 0
Sewerage ..	—	—	—	—	—	1,250,000 0 0				50,000 0 0		
Drainage ..	—	—	—	—	—	290,000 0 0				11,600 0 0		
Water ..	Sydney	23	Apr., 1934	12	9 Apr., 1946	650,000 0 0	1,000,000 0 0	100 0 0	3 15 0	24,375 0 0	37,500 0 0	5,000 0 0
Sewerage ..	—	—	—	—	—	320,000 0 0				12,000 0 0		
Drainage ..	—	—	—	—	—	30,000 0 0				1,125 0 0		
Water ..	Sydney	24	July, 1935	8	12 July, 1943	300,000 0 0	500,000 0 0	100 0 0	3 7 6	10,125 0 0	16,875 0 0	2,500 0 0
Sewerage ..	—	—	—	—	—	175,000 0 0				5,906 5 0		
Drainage ..	—	—	—	—	—	25,000 0 0				843 15 0		
Water ..	Sydney	25	Mar., 1936	15	1 Mar., 1951	600,000 0 0	1,000,000 0 0	98 0 0	4 0 0	24,000 0 0	40,000 0 0	5,000 0 0
Sewerage ..	—	—	—	—	—	400,000 0 0				16,000 0 0		
Water ..	Melbourne	26	Mar., 1936	15	20 Mar., 1951	375,000 0 0	500,000 0 0	98 0 0	4 0 0	15,000 0 0	20,000 0 0	2,500 0 0
Sewerage ..	—	—	—	—	—	110,000 0 0				4,400 0 0		
Drainage ..	—	—	—	—	—	15,000 0 0				600 0 0		
Water ..	Melbourne	27	July, 1936	15	3 July, 1951	275,000 0 0	625,000 0 0	97 5 0	4 0 0	11,000 0 0	25,000 0 0	3,125 0 0
Sewerage ..	—	—	—	—	—	350,000 0 0				14,000 0 0		
Water ..	Sydney	28	Aug., 1936	15	1 Aug., 1951	365,000 0 0	1,000,000 0 0	99 0 0	4 5 0	15,512 10 0	42,500 0 0	5,000 0 0
Sewerage ..	—	—	—	—	—	600,000 0 0				25,500 0 0		
Drainage ..	—	—	—	—	—	35,000 0 0				1,487 10 0		
Water ..	Sydney	29	Feb., 1937	12	1 Mar., 1949	425,000 0 0	1,375,000 0 0	98 12 6	4 5 0	18,062 10 0	58,437 10 0	6,875 0 0
Sewerage ..	—	—	—	—	—	900,000 0 0				38,250 0 0		
Drainage ..	—	—	—	—	—	50,000 0 0				2,125 0 0		
Water ..	London	30	May, 1937	20	1 Nov., 1957	†875,000 0 0	†2,500,000 0 0	100 0 0	4 0 0	28,000 0 0	80,000 0 0	10,000 0 0
Sewerage ..	—	—	—	—	—	†1,587,500 0 0				50,800 0 0		
Drainage ..	—	—	—	—	—	†37,500 0 0				1,200 0 0		
Water ..	Sydney	31	Jan., 1938	15	1 Feb., 1953	600,000 0 0	824,750 0 0	100 0 0	4 3 9	25,125 0 0	34,536 8 2	4,123 15 0
Sewerage ..	—	—	—	—	—	204,750 0 0				8,573 18 2		
Drainage ..	—	—	—	—	—	20,000 0 0				837 10 0		
							18,951,648 14 2				790,209 8 9	92,829 9 11

* Reduction under Interest Reduction Act 1931.

† Amounts represent equivalent in £A of 70,000, 1,270,000, 30,000 and 2,000,000 £ stg.

The following statement illustrates the expansion of the Board's financial operations over the whole period of its existence:—

	CAPITAL EXPENDITURE			Revenue	Working Expenses	Interest on Capital	Percentage Working Expenses to Revenue
	Water	Sewerage and Drainage	Total				
	£	£	£	£	£	£	
At 31st Dec., 1889	2,347,719	1,079,344	3,427,063	220,723	58,817	149,795	
" " " 1894	3,249,147	1,717,588	4,966,735	254,301	65,095	195,065	25.59
At 30th June, 1899	3,661,530	2,581,514	6,243,044	298,287	77,311	223,914	25.92
" " " 1904	4,289,012	3,824,530	8,113,542	379,101	101,120	274,581	26.67
" " " 1909	5,146,303	4,225,239	9,371,542	481,731	148,856	336,907	30.90[a]
" " " 1914	6,257,976	5,448,968	11,706,944	708,663	250,491	416,534	35.34[b]
" " " 1919	8,900,391	6,963,573	15,863,964	1,124,694	371,273	669,232	33.01
" " " 1924	13,094,176	8,145,061	21,239,237	1,861,637	624,887	1,057,732	33.57
" " " 1929	20,647,142	13,514,299	34,161,441	2,716,184	790,657	1,453,855	29·1[c]
" " " 1934	24,476,811	15,899,458	40,376,269	2,456,289	653,603	1,561,882	26.61[d]
" " " 1938	25,670,778	16,408,707	42,079,485[e]	2,783,324	800,442	1,540,148	28.75

[a] Rates were reduced between 1904 and 1909—water by 2d. in the £ and Meter rents abolished, Sewerage by 1½d. in £.

[b] Charge for water by measure reduced from 1s. to 11d. per thousand gallons. Rising costs of material and wages, the latter due to introduction of Wages Awards, show their effect on the relationship of Working Expenses to Revenue.

[c] The all-round increase in ratable values between 1924 and 1929 contributed largely to the reduction in ratio of working expenses to revenue here indicated.

[d] Reductions in living wage and general retrenchment due to economic depression more than offset reduced revenue brought about by fall in ratable values.

[e] Remission of Capital Indebtedness under Act 54 of 1935, to the extent of £7,500,000 for years 1936-1937 and 1937-1938 taken into account.

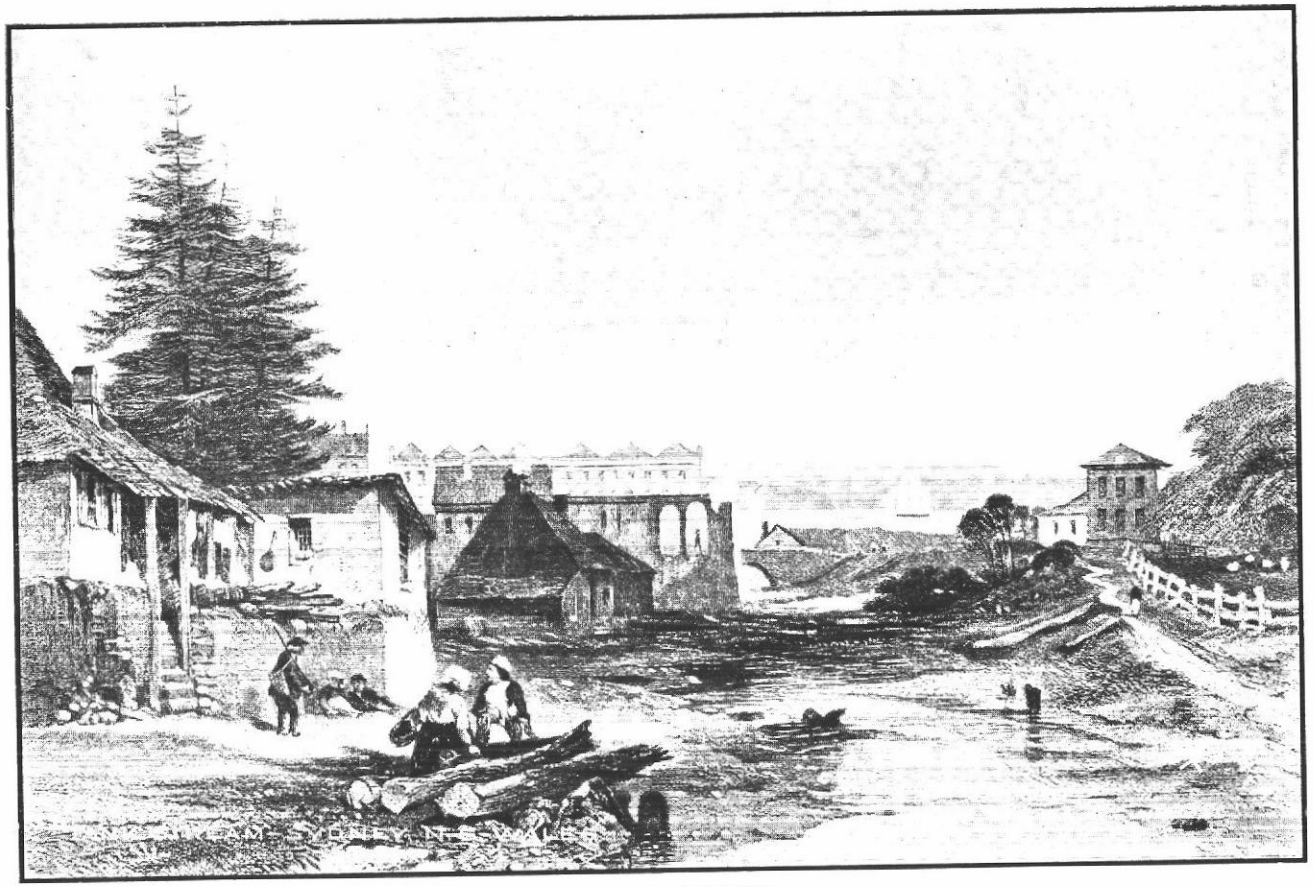
CHAPTER III

THE TANK STREAM—SYDNEY'S MAIN SOURCE OF WATER SUPPLY: 1788-1826

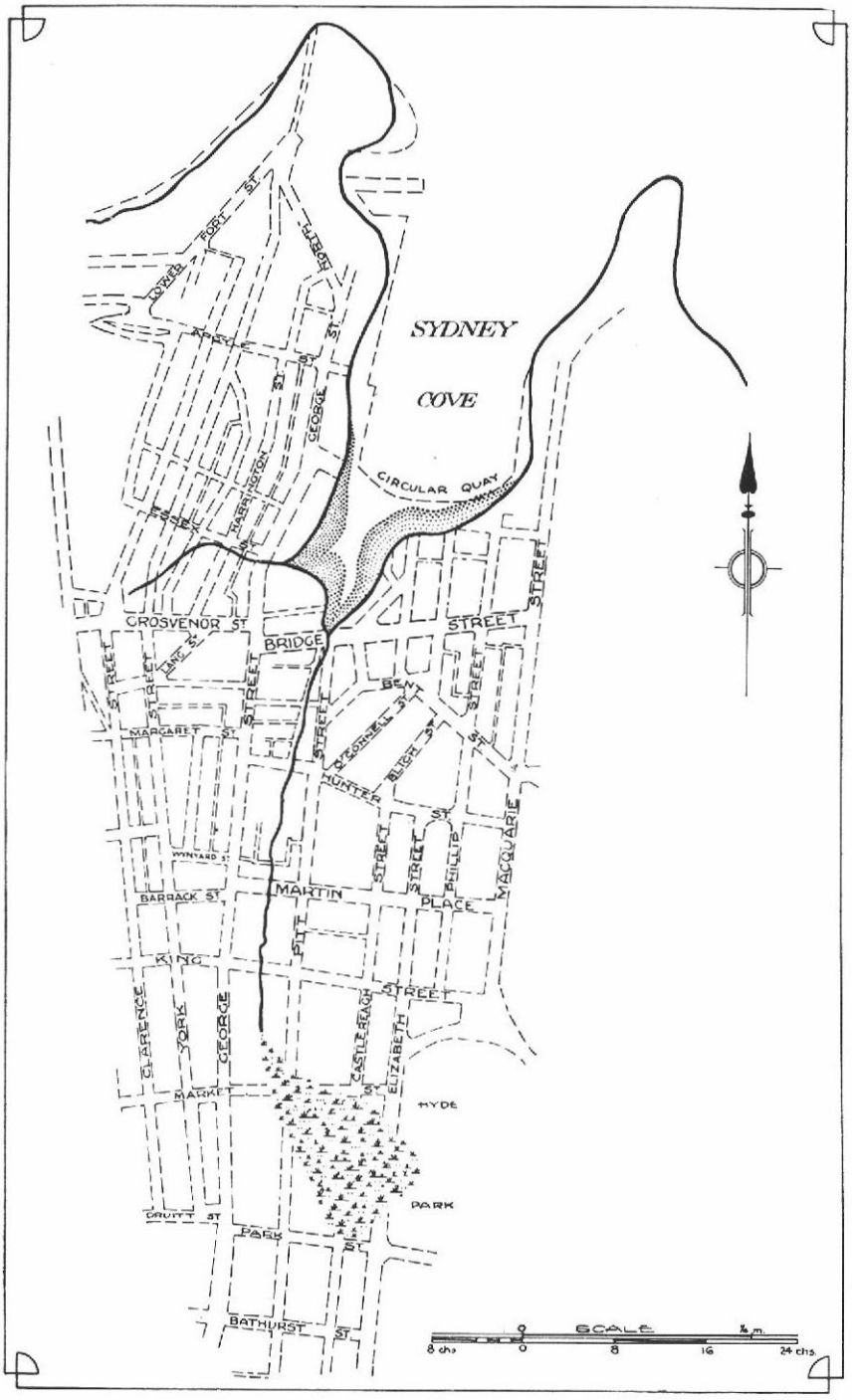
When Governor Phillip and a small party set out from Botany Bay a few days after the arrival there of the first fleet on 18th, 19th and 20th January, 1788, to ascertain whether a more suitable location for the settlement he had come to found could be discovered in Port Jackson, the first concern was to obtain a site which would provide a suitable water supply. The different coves of the harbour, we are told in *Phillip's Voyage to Botany Bay*, published in 1789, were examined, and the preference given to one which had the finest spring of water. In honour of Lord Sydney, the Governor distinguished it by the name of Sydney Cove, and the fleet being brought round from Botany Bay on 26th January, 1788, the tents and huts of the infant settlement were forthwith erected on the banks of the clear running stream. This rivulet, a little later, became known as the "Tank Stream," by reason of the fact that three tanks had been excavated near its channel at a point south of Hunter Street in what is now Hamilton Street.

The Tank Stream had its rise in marshy ground which skirted the western slopes of what is now Hyde Park between Market and Park Streets, and was fed from seepage springs issuing from the joints of the underlying sandstone at the head of the valley which at that time extended towards Oxford Street. The water filtered through the soil in a direction between Pitt and George Streets until it approached King Street, where the water formed a definite channel in its flow to Sydney Cove. The area it drained was about 160 acres, extending from Macquarie Street and a line continued therefrom through Hyde Park on the east, along Bathurst Street on the south to York and Clarence Streets on the west. The stream entered the high tide waters of the cove at about the middle of Bridge Street, where the first bridge was built.

The depredations of drought became an early source of anxiety, and as the town increased, the settlers began to dig wells and were successful in finding springs. A copious stream running into Blackwattle Swamp was also laid under contribution. The original source of supply at Sydney Cove, however, was, for a number of years, the main dependence,



THE TANK STREAM.



THE VALLEY OF THE TANK STREAM.

and strenuous efforts were made from time to time to husband its resources and protect its purity.

Thus, in the Sydney Gazette of 18th December, 1803, a general order was published of which the following is an extract:—

> "If any person whatever is detected in throwing any filth into the stream of fresh water, cleaning fish, washing, erecting pigsties near it or taking water out of the Tanks, on conviction before a Magistrate their house will be taken down and forfeit £5 for each offence to the Orphan Fund."

To further protect the purity of the supply, fences were later erected along the course of the stream and around the tanks, and direct access to the stream any other way than at the tanks was forbidden. Later in 1810, it was found necessary for the Governor to issue more stringent regulations prohibiting the continuance of certain industries adjacent to the stream and tanks.

In 1811, drought again threatened the community and in the Sydney Gazette of 2nd March, 1811, it is reported that:—

> "The long prevailing drought has destroyed every hope of the maize crop which is unfortunately past recovery. A scarcity of water more acute than ever before experienced has also been the consequence. In Sydney the tanks have been several weeks empty and those who were in want of water were obliged to collect it from small cavities in the spring course above the Tanks, which has afterwards been sold at from fourpence to sixpence per pail."

Heavy rains fell soon afterwards and for several years following (with the exception of 1814-15), floods were more a characteristic than droughts.

In 1820, drought conditions again beset the community causing a Gazette notice to be issued calling upon the people to strictly observe all regulations laid down for conserving the purity of the supply and concluding with the following observation:—

> "With much pain we have lately observed individuals washing themselves in this stream of water, particularly in that part that runs centrally from King Street because that spot is almost secluded from every eye, that of curiosity excepted."

The history of the Tank Stream for the remaining years of its existence as a source of water supply is one of succeeding droughts and pathetic attempts to preserve it from pollution. Orders of the Government in this direction were all in vain, and the conclusion is gathered from the available records that it ceased to be a source of water supply after 1826.

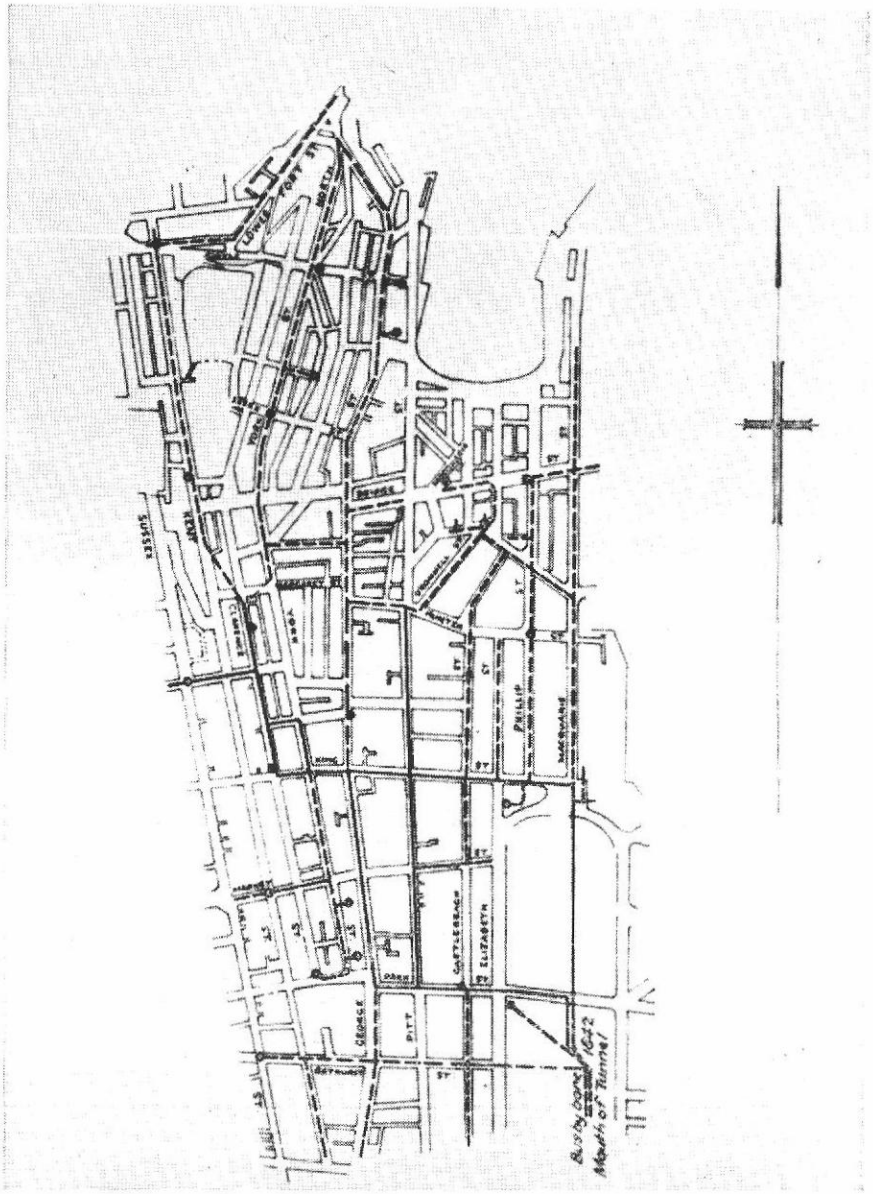
For some years following, the settlers were dependent upon wells

and rainwater collected in water butts (iron tanks were not then in use), which was distributed by water carriers.

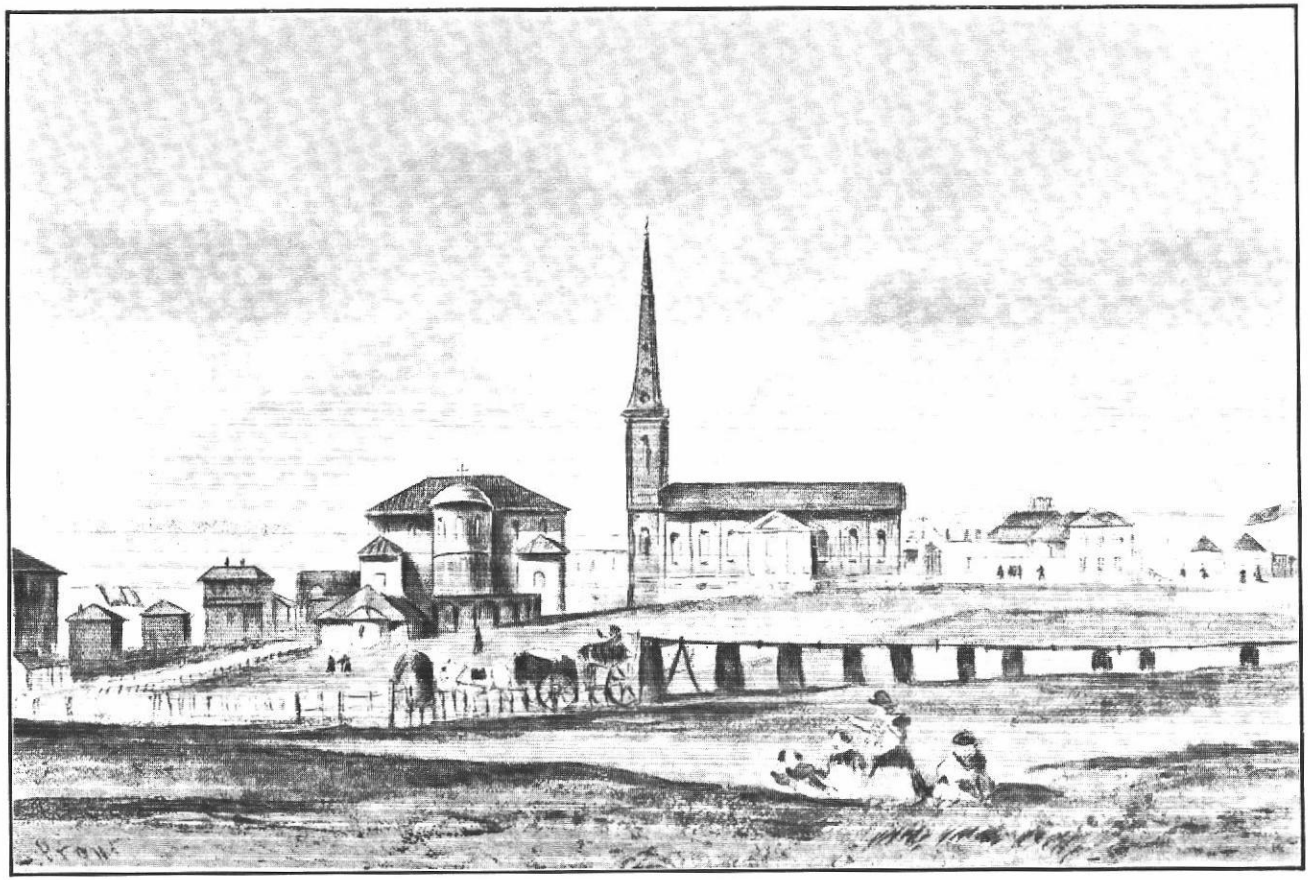
In 1850, the progress of laying out the City rendered it necessary to drain the swamp area which fed the Tank Stream and this resulted in the latter becoming very little more than an open sewer. By 1860, steps had been taken to cover it in, and a tunnel, reaching from Hunter Street to Bridge Street, was constructed where it connected with a sewer which had been laid by the City Commissioners five or six years earlier, emptying into Circular Quay. About seven years later an oviform sewer was completed along the channel between Hunter and King Streets, part of which remained for a time uncovered. The erection of the General Post Office and the formation of Martin Place during the eighteen seventies, and later on, the widening of that thoroughfare, necessitated the covering in of the central portion of the open drain. Later, an 18-inch line of stoneware pipes was laid along the upper end of the channel between King Street and the old Royal Hotel, which stood on the site in George Street now occupied by Dymock's Book Arcade, and finally, the remaining open parts of the stream between King and Hunter streets were arched over. Thus was the transformation of the Tank Stream, from a source of water supply of the early settlement into a main sewer for succeeding generations, complete. Truly may civilisation and progress be regarded as somewhat paradoxical in their inevitable results!

REFERENCES

Sydney Gazette, 18th December, 1803.
Sydney Gazette, 2nd March, 1811.



PLAN OF SYDNEY'S FIRST RETICULATION SYSTEM.



BUSBY'S BORE.

CHAPTER IV

BUSBY'S BORE—SYDNEY'S SECOND SOURCE OF WATER SUPPLY 1830-1858

The year 1826 began with heavy rain and floods but soon changed to a prolonged drought. The population of Sydney had grown to 10,000 and the Tank Stream in its polluted condition was no longer suitable or adequate to meet the needs of the community.

In 1824, Mr John Busby had arrived in the Colony as Mineral Surveyor to the Government, and his labours were soon turned by the Governor (Sir Thomas Brisbane) to a search for water. After examining several localities near Sydney, he ultimately reported (in 1826) in favour of drawing a supply from the Lachlan Swamps which covered an area the major portion of which is now Centennial Park, the swamps being represented by the lakes in that Park.

Mr Busby's plan was to drive a tunnel from the swamps to Hyde Park (then known as the Racecourse), where he proposed to excavate a reservoir capable of holding 15 million gallons. The scheme for the tunnel was adopted, but the reservoir was excluded. Operations commenced at the south-eastern corner of Hyde Park in September, 1827. As work proceeded, seepage springs were tapped, and from this source, the tunnel, in 1830—long before its completion—began to supply water to the public, in quantities sufficient for all immediate requirements, by means of a pipe carried a short distance into Hyde Park on trestles to enable the filling of water carts.

Later, in 1833, the water was conveyed in pipes to the Port for the use of shipping, and Governor Bourke, in a despatch in that year, stated that—

> "A new source of revenue has been opened this year (1833) by the supply of water for the shipping brought by pipes to the dockyard. The object of bringing water to this point is the convenience of the Merchant Vessels frequenting the port, but at the low rate of 1s. 0d. per ton, a revenue of £250 per annum may be collected. It is confidently expected that, at no distant period, a supply of water may be more productive of revenue, by disposing of it at a certain rate to such inhabitants of Sydney as may desire to have the water brought to their houses."

Due to the unmanageable and unskilful character of the labour (convict), and unforeseen difficulties in the strata, the tunnel for its full length was not completed until June, 1837.

It commenced at a point adjacent to what is now the entrance to Centennial Park from Cleveland Street, and its route to Oxford Street extended through the Agricultural Society's ground and the old Paddington Rifle Range across Park Road and through Victoria Barracks grounds.

From the termination of the bore or tunnel adjacent to the Oxford Street entrance to Hyde Park, the line of pipes before referred to as above ground supported on trestles for part of the way was extended to a point near the present tram stop at the corner of Park and Elizabeth Streets, at which point the regulator was fixed and the supply drawn off by water carts and other receptacles.

The bore was 12,000 feet in length; average height 5 feet; average width 4 feet. It had twenty-eight vertical shafts ranging from twenty to twenty-eight feet in depth and is reputed to have cost £24,000. It had a capacity of from 300 to 400 thousand gallons per day, which was considered an adequate supply for the needs and population of Sydney at the time (20,000).

Soon after the completion of the tunnel, there commenced a calamitous drought which extended from early in 1838 to May, 1839. The supply through the tunnel became scanty during this period and the *Herald* of 5th November, 1838, contains the statement that "three pence per bucket is the price now asked—a heavy tax upon poor people." The normal price was 1s. per cask, later reduced to 6d. Connection to the bore was permitted at a fee of 10s. per annum.

In 1844, the proposal mentioned by Governor Bourke in his despatch of 1833 was given effect to, and reticulation pipes from the bore were laid to various points in the City, about 70 houses being immediately connected. The charge made was 5s. per room per annum. In addition, fountains from which water could be drawn off by all and sundry were established at various points in the town. The map opposite page 44 shows approximately the layout of this reticulation and the position of the fountains.

It will be noted that two 9-inch mains (shown on the map by firm black lines) conveyed the water to various 3-inch distributaries. One of these mains ran through Hyde Park to the top of King Street, and thence by that street and Clarence Street to Margaret Place, and the other by Park and Pitt Streets to Hunter Street.

In 1854, a small pumping plant was installed at the lower end of the swamp for the purpose of increasing the flow, dams having meanwhile been constructed at several points to conserve the water. With this supplementation, Busby's Bore continued to be Sydney's sole source of

supply until 1858, when the Botany Swamps Water Supply Scheme was brought into operation. However, 11 years later (1869), it is recorded that the bore was still distributing water to parts of Woolloomooloo and Darling Harbour.

In 1902, when the level of water in Prospect Reservoir (then the only storage available) had been reduced to below gravitation level owing to prolonged drought, various means were sought of conserving the available supply, and as a large quantity of water was required for the Botanic Gardens, an arrangement was made with the Chief Secretary's Department, under which the Board laid a 3-inch main from a junction in Busby's Bore in Oxford Street at the top of Yurong Street through the Domain to the Gardens. In view of the likelihood of the water being more or less polluted, it was ultimately decided that it would be dangerous even to convey it into a separate garden supply reticulation for fear children or adults might drink from the garden hose. The use of the flow from the Bore was, therefore, confined to flushing the creek and ponds in the gardens and replenishing them when necessary.

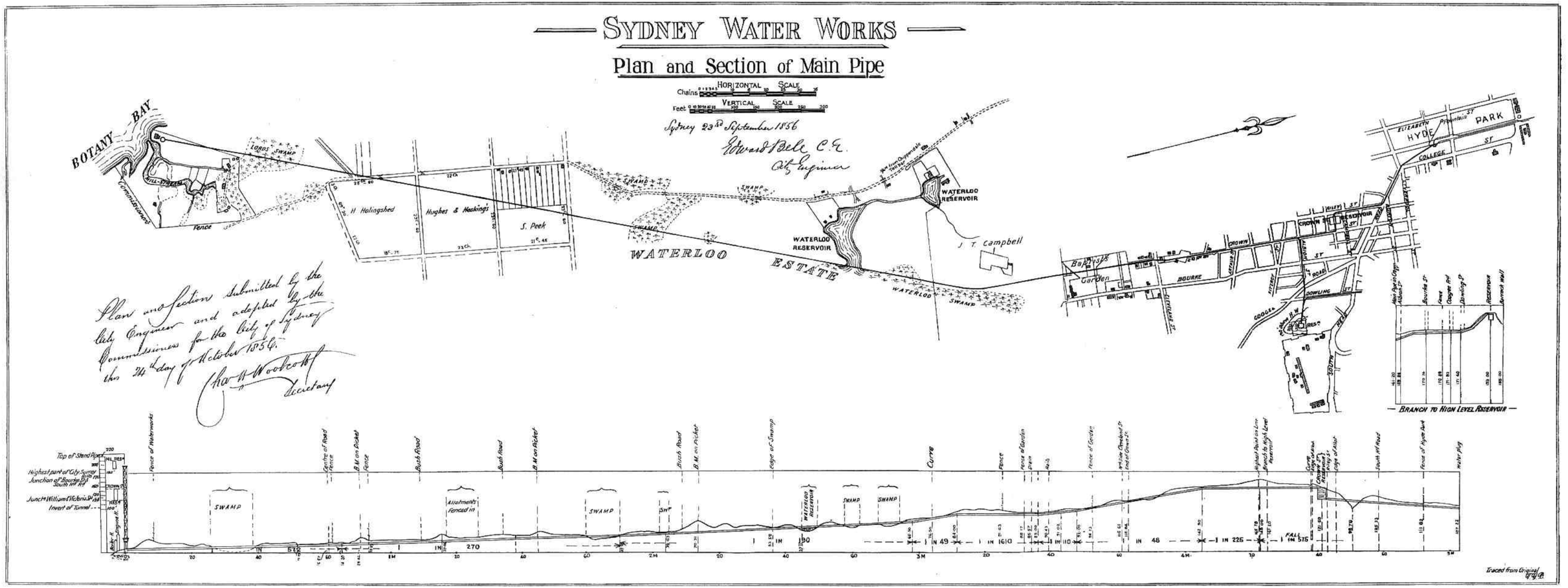
In 1934, owing to subsidence over the tunnel endangering the section of tram lines in Oxford Street, the tunnel from the intersection of College, Liverpool and Oxford Streets to a point near Riley Street, was filled in with sand blown in by compressed air and water jet, and so compacted in the tunnel.

CHAPTER V

THE BOTANY SWAMPS—SYDNEY'S THIRD SOURCE OF WATER SUPPLY: 1858-1886

In 1849, there occurred another drought of considerable severity (the rainfall at South Head measuring only 21½ inches as compared with the usual annual average of about 50 inches), and the question of a more adequate source of supply for the increasing population (now 40,000) again came into prominence. The responsibility for this matter now rested with the Municipal Council of Sydney, which had come into existence by virtue of Act 3 Vic. No. 6, passed on 20th July, 1842 (the first Council being elected on 1st November, 1842), and in 1849 it directed the City Surveyor (Mr Francis Clark) to examine the existing source of supply, with a view to seeing whether it was capable of being made to yield a greater volume of water. His recommendation was that a dam should be constructed across the lower part of the Lachlan Swamps and thus a lake be formed to provide suction water for a pump to lift water into a reservoir adjacent to the tunnel. This, however, was not given effect to, and in January, 1850, a Special Committee of the Council was constituted "to inquire into and report on the best means of procuring a permanent supply of water to the City of Sydney." The Committee did not complete its labours till February, 1852, when it submitted a long and carefully compiled report, recommending the supplementation of the Lachlan Swamps supply by drainage eastward to Bunnerong and westward to Shea's Creek and Cook's River. This report stated the population of Sydney at nearly 50,000 (there having been a recent large accession in consequence of the discovery of gold), and the number of houses at 8482 (of which only 2300 were supplied with water). The assessed annual value of City property was given as £232,678, and the gross water revenue as £3493 per annum.

Before any action could be taken on this recommendation, the Governor (Sir Charles FitzRoy) appointed in January, 1852, a Board of five members to examine the question afresh. It did not take up, as the City Council's Committee had done, the merits of different schemes, but restricted itself to an examination of the Botany Swamps as being undoubtedly the best available source, and its report, which was laid before the legislature seven months later, made recommendations which em-



BOTANY WATER SUPPLY—SYDNEY'S THIRD SOURCE OF WATER. (1858 TO 1886)

braced what were, later on, the main features of the Botany Swamps Water Supply Scheme. This source of supply consisted of the Lachlan Swamps and the swamps and streams leading thence to Botany Bay.

In January, 1854, the management of the City passed from the hands of an elective council to three Commissioners appointed by the Governor, who functioned for a period of three years. The Commissioners took up zealously the question of water supply and passed speedily from enquiry to action. In 1854 (a very dry year in Sydney), they erected a small pumping engine at the lower part of the Lachlan Swamps for the purpose of throwing more water into Busby's Bore, thus adding about 150,000 gallons to the daily delivery. At the same time, they entered on the preliminaries of the Botany Swamps scheme which was to supersede the supply from the Lachlan Swamps via the Bore.

In November, 1858, the first stage of this scheme was brought into being by the installation of three steam pumping engines of 100-h.p. each, in a building erected near the shores of Botany Bay. The suction water for the pumps was drawn from what was known as the Engine Pond, created by a low dam built by convict labour as far back as 1838. A 30-inch main about four miles long was constructed from the pumping station to a reservoir built at Crown Street and completed in 1859, 141 feet above sea-level, holding $3\frac{1}{4}$ million gallons, and later (1864) one at Paddington, 214 feet above sea-level, holding $1\frac{1}{2}$ million gallons. (It is worth recording that a section of the 30-inch main along Crown Street as far as Devonshire Street is still brought into use when it is desired to boost water to Centennial Park Reservoirs). As there was no telegraphic or telephonic communication with Botany in those days, a column or standpipe was erected near the Victoria Barracks, the top being at the same level as T.W.L. Paddington Reservoir. This was carefully watched with a telescope from the Botany pumping station, and as soon as it was seen to overflow, showing Paddington Reservoir to be full, the pumps were stopped.

In 1879, a pumping plant was erected at Crown Street Reservoir to lift the water up to Paddington Reservoir, and in 1881, a supplemental plant was installed to raise the water up to Woollahra Reservoir, which had been completed in 1880. In 1886, a small pumping plant was erected at the back of the Woollahra Reservoir to lift the water to a new reservoir at Waverley Park, completed by the Government in 1887.

In 1862, or four years after the erection of the pumping plant at Botany, the consumption had so increased owing to growth of the City and extension of the supply to the suburbs (at that time, water was being distributed throughout the whole of Sydney proper, together with the Municipalities of Glebe, Darlington, Redfern, and part of Paddington, by about 105 miles of piping) that it became necessary to consider the question of constructing dams along the course of the Botany Swamps

to provide storage. Two Select Committees of the Legislative Assembly were appointed, one in 1862 and the other in 1864, to report on the matter of proposed alienation of certain portions of the Water Reserves, but no definite recommendations were made by either Committee.

Early in 1867, the City Engineer (Mr Edward Bell) prepared plans and specifications for the construction of a number of these, and work was commenced thereon in the same year. According to a report in the *Sydney Morning Herald* of 24th June, 1867, they were formed of a strong framework of beams, bolted together with iron, presenting two walls or faces on which planks were closely fitted together vertically. These frames were given an outward slope to provide more effectual resistance to the force of accumulated water, and the wide space between the two outer faces of the framework was filled with mud and sand. Heavy rains fell about 2nd July, 1867, and the three dams (Nos. 1, 2 and 3) then under construction were seriously damaged. Work on the construction of three additional dams (Nos. 4, 5 and 6) seems to have been commenced about August, 1867. Towards the end of October of that year, heavy rains again fell and a report by the *Sydney Morning Herald* states that No. 3 dam gave way, and Nos. 4 and 5 were injured.

Early in February, 1868, heavy rains fell over the area, 6 inches being registered in one day and 9 inches in two. Several of the dams burst on the 17th, and according to a report appearing in the *Sydney Morning Herald* on 24th February, 1868, Nos. 1, 2 and 3 dams were practically wrecked. Somewhere about 1873 the dams were reconstructed.

Sydney and suburbs continued to be served with a water supply solely from this source until 1886. In January of that year, owing to threats of a water shortage, connection was made by temporary fluming between Botany and the Upper Nepean scheme, which at that time had reached an advanced stage of construction, and water was delivered from Prospect Reservoir into the Botany storage to temporarily augment same. This work, known as Hudson's Temporary Scheme, is dealt with in Chapter VII.

In November, 1886, the Botany supply was superseded by the supply from the Upper Nepean Scheme.

With the creation in 1888 of the Board of Water Supply and Sewerage, the Botany Water Supply Works became vested in that body.

The pumping plant was kept in efficient working order to meet any emergency until 1893, when it was considered that the supply from Prospect, with the duplication of the trunk main from Potts Hill to Crown Street, rendered it no longer necessary to observe this precaution. In the intervening years, however, the Botany engines had to be put into action on two or three occasions to assist in tiding over interruptions to the supply from Prospect due to bursts in the then single line of the 48-inch main between Potts Hill and Crown Street.

The quantity of water pumped to Crown Street during 1886 (the last year of full use of the pumps) was 1,864,123,400 gallons.

The Botany pumping plant was dismantled and sold at auction in 1896. The old pumping station building still stands, although in a state of dilapidation, the chimney stack being used as a vent shaft for the Southern and Western Outfall Sewer.

With the discontinuance of the use of the area for domestic water supply, the Board decided to lease, with water rights, portions of it at the southern end of the Reserve adjoining the lower dams. As time went on, practically the whole of the land available for occupation in this way was taken up by various companies and firms for wool-scouring, and at the present time extensive industries of this and an allied nature are established here, for which the water obtainable is particularly suitable. The well-known Lakes and Eastlake Golf Courses occupy portions of the catchment area under lease.

The area of the Botany Water Reserve as originally vested in the Board was 330 acres. In 1911, following developments which threatened to interfere with the effective control by the Board of the water storage contained in the four upper dams which were enclosed by privately owned land, the Board acquired by resumption an additional area, between Gardeners Road and the northern boundary of the original reserve, of 267½ acres. Of this area, 63¼ acres were appropriated in 1912 by the Government for Daceyville Garden Suburb, the Board being compensated for the value of the land so taken. Two or three other small areas also acquired bring the total area now held to 528 acres, of which 183 acres are submerged by the dams and swamps.

On 7th July, 1931, following exceptionally heavy rainfall, a number of the dams were badly damaged, and a large volume of water being released, serious flooding occurred at the Botany Bay end of the Reserve, washing out and destroying a culvert under Botany Road and temporarily interrupting traffic, both tramway and vehicular. The leaseholders and other interests also suffered considerable damage. In order to meet the requirements of the industries established on the leaseholds, the Board restored the dams to the extent necessary for this purpose, the work being carried out on lines likely to ensure their future stability.

REFERENCES

Progress Report from the Select Committee on Sydney Water Reserves, 1864.

Report of Royal Commission appointed to enquire into the supply of water to Sydney and Suburbs, 1869.

Report to Government by W. Clark, M.Inst.C.E., on various projects for supplying Sydney with water, 1876-1877.

Sydney Morning Herald, 24th June, 1867.

Sydney Morning Herald, 24th February, 1868.

CHAPTER VI

UPPER NEPEAN SCHEME—SYDNEY'S FOURTH AND PRESENT SOURCE OF WATER SUPPLY—INITIAL STAGE, 1867-1888

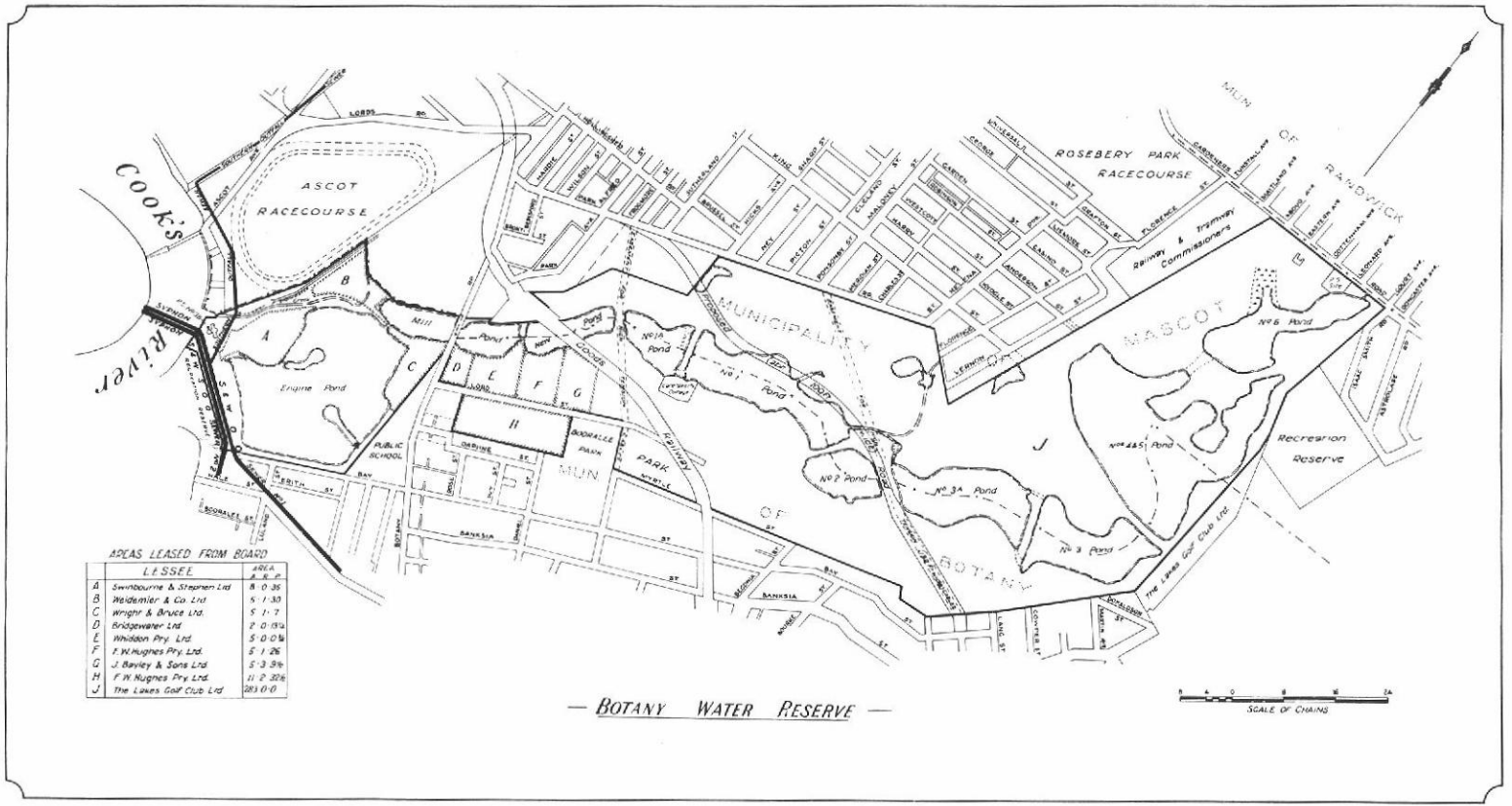
In 1867, nine years after the water supply from the Botany Swamps had first been brought into operation, the population of Sydney and suburbs had grown to such an extent that it was necessary to consider how still further supplies could be obtained. Recurring dry seasons added to the anxiety felt in responsible quarters.

Accordingly, the Governor (Sir John Young) on 24th September, 1867, appointed a Commission for this purpose, with instructions to recommend a scheme considered capable of providing a reliable and plentiful supply for future requirements. This Commission, consisting of

Mr John Smith, M.D. (Professor of Physics, etc., Sydney University),
Mr Edward Orpen Moriarty, M.A., M.Inst.C.E. (Engineer-in-Chief Harbours and Rivers),
Mr Phillip Francis Adams (Deputy Surveyor-General),
Mr Francis Henry Grundy, C.E. (Civil Engineer), and
Mr Thomas Woore, R.N.,

made investigations extending over a period of two years, and collected a mass of evidence from various quarters on a number of proposals, including supplies from the Grose River, the tributaries of George's River, the Warragamba River, the Upper Nepean River, and from the last named stream at Penrith. It finally decided, in 1869, to recommend the Upper Nepean scheme as possessing the leading qualities sought in all great water supply projects throughout the world. This scheme embraced the tapping of the head waters of the Nepean River and its tributaries, the Cataract, Cordeaux, and Avon Rivers.

The catchment area of these streams comprises 347 square miles of country on the top of the South Coast Range, extending from opposite Clifton on the north-east to Robertson on the south-eastern corner, thence across to Mittagong at the south-western corner to near Appin on the north-west. It is described in the Commission's report as "entirely a sandstone country, of a barren intractable nature, and if not turned to account as a gathering ground for water, as never likely to be of much use for anything else."



AREAS LEASED FROM BOARD

	LESSEE	AREA A. R. P.
A	Swinbourne & Stephen Ltd	8 0 36
B	Waldemar & Co. Ltd.	5 1 33
C	Wright & Bruce Ltd.	5 1 7
D	Bridgewater Ltd.	2 0 15½
E	Whiddon Pty. Ltd.	5 0 0¼
F	F. W. Hughes Pty. Ltd.	5 1 26
G	J. Bayley & Sons Ltd.	5 3 9¾
H	F. W. Hughes Pty. Ltd.	11 2 20½
J	The Lakes Golf Club Ltd.	283 0 0

— BOTANY WATER RESERVE —

SCALE OF CHAINS

The Commission's recommendations involved the construction of:—

(i) A weir across the Upper Nepean River at Pheasants Nest, just below its junction with the Avon and Cordeaux Rivers, by which a proportion of the flow of these streams was to be diverted into a tunnel to connect with the Cataract River.

(ii) A similar weir across the Cataract River at Broughton's Pass by means of which the intermingled waters of the four streams were to be turned into a conduit 36 miles long (later known as the Upper Canal), consisting of a series of tunnels, open canals and aqueducts.

(iii) A storage reservoir of 11,000 million gallons capacity at Prospect.

(iv) A canal (now known as the Lower Canal), 5 miles long, from Prospect Reservoir, terminating in a basin at Guildford (now known as Pipe Head basin).

(v) A wrought iron pipe line, 6-ft. in diameter and 5 miles in length, from the basin at Guildford to a service reservoir with a capacity of 96 million gallons at Potts Hill, together with a 48-inch cast iron pipe from that reservoir to the existing reservoir at Crown Street, with a branch into a new reservoir to be built at Petersham.

From these two latter reservoirs, the Prospect water was to be fed into the reticulation system of Sydney and suburbs previously distributing the Botany Supply.

The Commission estimated the cost of its proposed works at £800,000.

An interesting portion of the report, having regard to much later developments, states:—"At first we considered the propriety of forming dams on the rivers themselves, and we examined a portion of their channels with that view; but although we found several points tolerably well fitted for dams of considerable capacity, we ultimately decided not to recommend the construction of any of these for the present. The heavy floods to which all our rivers are subject would render such dams unduly expensive, and we considered that it would be more economical, as well as in other respects preferable, to construct one large reservoir apart from the rivers and subject to no floods, instead of several dams of smaller capacity in the river beds."

In regard to the details of the scheme, the one point on which there seems to have been difference of opinion was the site of the proposed storage reservoir. Mr Grundy favoured a reservoir at Bull's Hill on one of the heads of Prospect Creek, about the 38th mile from the weir at Pheasants Nest. He maintained that at this site in normal seasons the water could be brought to Sydney by two lines of pipes, one to supply Crown Street Reservoir (low level service), and the other the Padding-

ton Reservoir (high level service). Mr Moriarty, however, favoured the location of the reservoir two miles farther on at Prospect, where the maximum water level would be lower than at Bull's Hill and would not exceed 195-feet above sea level.

The main grounds on which the Commission decided to recommend the reservoir at Prospect were:—

(i) Prospect Reservoir would have much greater storage capacity than Bull's Hill, with less height and cubic contents of the bank.

(ii) Bull's Hill could not be relied upon to supply by gravitation any locality higher than Paddington Reservoir.

(iii) The scheme with the reservoir at Prospect instead of Bull's Hill was estimated to cost £250,000 less, allowing for capitalized cost of pumping at Crown Street.

When engaged on surveys of the route of the Canal, Mr F. B. Gipps, an engineer of Public Works Department under Mr Moriarty, discovered a third site for the proposed reservoir, viz. at Kenny Hill, near Campbelltown. This site, although it did not receive the support of the Commission, and is not commented on in Mr Clark's later report reviewing the whole matter, found many advocates at the time. (In 1902, when Sydney was threatened with a water famine and a Royal Commission was appointed, as related farther on, to enquire into the Sydney Water Supply, Mr Gipps' proposal of over thirty years back for a reservoir at Kenny Hill was revived by press correspondents who had a knowledge of the matter. However, it was recognised that whatever merits this site may have had prior to the construction of the Prospect Reservoir, it had no virtues in the emergency then existing, by which time the growth of the Metropolis in the fifteen years since Prospect was built had been such that the water supply position could only be adequately safeguarded by the construction on the rivers of storage dams previously foreshadowed, to hold back the surplus waters which, in times of flood rains, escaped over the diversion weirs at Pheasants Nest and Broughton's Pass.)

The Commission supplied statistics showing that the estimated annual value of property in the City and suburbs in 1869 was about £1,100,000, and that a rate of 1s. 0d. in the £ would return an adequate revenue to meet annual charges.

The Commission's proposals were not immediately proceeded with, but after a lapse of six years, during which a number of alternative schemes were promulgated from various sources, and the population had grown to 180,000, the Government of the day decided to obtain an independent opinion, and to this end engaged the services of Mr W. Clark, M.Inst.C.E., an eminent civil engineer in England, to come to

the Colony for the purpose of advising it on the Water Supply and Drainage of the City of Sydney. Mr Clark arrived on 29th November, 1876, and after considering no less than eight schemes, of which the principal were:—

(1) Upper Nepean.
(2) Loddon Creek and Wingecarribee Swamps.
(3) Lower Nepean (Penrith)—Pumping Scheme.
(4) Warragamba.
(5) George's River (with dam at estuary outlet)—Pumping Scheme;

recommended on 15th May, 1877, the Upper Nepean Scheme at an estimated cost of £1,086,768, stating that he considered it to be much superior to any of the other proposals as a source of supply, possessing capabilities of future development and supplying the water at the cheapest rate. He also endorsed, for the same reason as actuated the majority of the Commission, their preference for a reservoir at Prospect rather than at Bull's Hill.

Mr Clark, supplemented the Commission's proposals by recommending the increase of the capacity of Petersham Reservoir from 800,000 to 2,000,000 gallons, and the provision of additional reservoirs at Newtown, Woollahra, and Waverley.

Following the passage, in July, 1879, of an Appropriation Act authorising the raising of a loan for certain public works, amongst which was included an amount of £1,086,768 for the Upper Nepean Scheme, work was commenced in 1880, and the whole scheme completed in 1888 at a cost of £2,076,313.

The following description of the work as carried out has been adapted from a paper by Professor W. H. Warren, the first Professor of Engineering of the University of Sydney, presented to the first meeting of the Australasian Association for the Advancement of Science held at Sydney, in August and September, 1888, and published in the reports of that body:—

"The present water supply of Sydney is derived from the Upper Nepean, the Cordeaux, and the Cataract Rivers, at a level sufficiently high to supply Sydney by gravitation.

The drainage area comprises three hundred and fifty-four square miles entirely in a sandstone country, which is at present practically unoccupied, and likely to remain so, since the country is sterile and consequently unsuitable for agricultural and pastoral pursuits.

The rivers above referred to rise in the mountain country running parallel to the coast, between the Bulli Pass and the Mittagong Range, and which attains an elevation of 1000 feet and upwards. The mountains present a very precipitous face towards the sea, with a more gentle slope landwards; they thus form a barrier to intercept the rain clouds

coming from the sea, which condensing, discharge their water on the extended area of these landward slopes.

A comparison of the records of rainfall near the coast with that more inland will show the larger rainfall is deposited soon after the clouds pass the summit of the range. The quality of the water from such a source as the one above referred to is unquestionable. There are, moreover, numerous swamps in the upper portion of the catchment area which retain the water falling upon it, preventing its rapid discharge by the rivers, and rendering their flow more equable.

These rivers, like all those in the sandstone country, have cut their way into narrow gorges of a very rugged character, till their waters reach, in a comparatively short distance, a level very little above that of the sea. The sides of these gorges are thickly covered with timber.

From Pheasant's Nest, which is a gorge of the character above described, just below the junction of the Cordeaux with the Nepean, the waters of the united streams are held back and raised to a height of 439.5 feet above the sea level by means of a dam about ten feet high, which is constructed across the Nepean.

The Nepean Tunnel which unites the waters of the rivers referred to with those of the Cataract River, commences at the dam, with an invert level of 430 feet above the sea. It is 23,507.25 feet long, nine and a half feet wide, and seven and a half feet high, driven through the sandstone rock and inclined on a gradient of two and a half feet per mile, having a discharging capacity of 97 millions of gallons daily.

At Broughton's Pass another similar dam is constructed, about 12 feet in height, across the Cataract River, by means of which the combined waters of the Nepean, Cordeaux and Cataract are raised to a level of 426 feet above the sea, and are then conveyed by the Cataract Tunnel, which commences with an invert level of 416 feet above the sea, being a drop of about two feet below the invert level of the Nepean Tunnel at this point; it is 9724·33 feet long, 10½ feet wide, and 8½ feet high, driven through the sandstone rock on a grade of three and a half feet per mile, and having a discharging capacity of 155 millions of gallons per day.

On leaving the Cataract Tunnel, the outlet of which is a little over 6¼ miles from the Pheasant's Nest, the water is conveyed for several miles through very rugged country, intersected by deep creeks.

From the mouth of the tunnel, and for a length of 1133 feet, the 3½ feet per mile gradient is continued, the canal being cut out of the rock and having a width of nine feet, it then gradually widens to 12½ feet, with vertical sides, and a fall of 21 inches per mile, the depth of water being 8 feet when running full.

In excavating the canal over this portion and for some distance on, where the foundation is sandstone, every endeavour was made to

save the rock in places where it appeared that lining could be dispensed with. When it became necessary to protect the sides, the lining is composed for the most part of dry rubble masonry; in places where the cutting was shallow, or the ground very bad, walls of concrete or of rubble in cement were built.

The creeks are spanned by large wrought-iron pipes or syphons, on stone piers or bearers, with concrete abutments.

The following are the particulars of the aqueducts:—

Simpson's Creek at the seventh mile.—Diameter of pipe, 8 feet. Spans—two, 12 feet; two, 33 feet; and one, 60 feet, making a total length of 150 feet between abutments; gradient, one in 524·445; height of pipe above flood level in creek, 20 feet.

Elladale Creek at seven and three-quarter miles.—Diameter, 8 feet. Spans—two, 12 feet; two, 23½ feet; four, 33 feet; six, 35 1/3 feet; and four, 60 feet; total length, 655 feet. The form of this flume is an inverted syphon lowering the centre portion to 31 feet below the bed level of the canal, and 39 feet above flood level. This arrangement avoids unnecessary height of piers. The gradient is one in 699·786.

Ousedale Creek at a little beyond nine and a quarter miles.—Diameter, 7½ feet. Spans—two, 12¼ feet; two, 31 feet; three, 33 2/3 feet; three, 37½ feet; and two, 60 feet. Total length, 420 feet. The form is an inverted syphon, the centre portion being 29 feet below bed level of the canal, and 41 feet above flood level. The gradient is one in 433·884.

Mullaly Creek at a little over nine and three-quarter miles.—Diameter, 7½ feet. Total length, 170 feet. Gradient, one in 425 feet.

Leafs Creek at eleven miles.—Diameter, 7½ feet. Spans—two, 7½ feet; one, 37 feet; one, 38 feet; and three, 60 feet. Total length, 270 feet. Form inverted syphon, centre portion being 34 feet below bed level of canal, and 42 feet above flood level. Gradient, one in 459·965.

Nepean Creek at eleven and three-quarter miles.—Diameter, 7½ feet. Spans—two, 12 feet; two, 38 feet; one, 60 feet. Total length 160 feet. Height above flood level, 12 feet. Gradient, one in 489·296.

Woodhouse Creek at twelve and three-quarter miles.—Diameter, 7½ feet. Spans—two, 12 feet; two, 48 feet; and two, 60 feet. Total length, 240 feet. Height above flood level, 47 feet. Gradient, one in 382·155.

Menangle Creek at fourteen and a quarter miles.—Diameter, 7½ feet. Spans—two, 12 feet; one, 30½ feet; two, 60 feet; and five, 3½ feet. Total length, 332 feet. Height above flood level, 15 feet. Gradient, one in 431·729.

The smaller creeks and watercourses are carried either under the canal by brick syphon culverts or over it by wrought-iron or timber flumes. At a little beyond the tenth mile the water passes into Devine's Tunnels, 600 feet and 2680 feet in length respectively, driven through the sandstone rock, and being of the same dimensions and gradient as

the greatest depth will be 75 feet, and the depth from which water will be drawn 25 feet, giving an effective storage capacity of 7110 million gallons. The reservoir is formed by the construction of an earthen dam, 110 chains long and 85 feet high in the deepest part, the width at the top will be 30 feet, the slopes are three to one inside and two and a half to one on the outer side with 15 feet berms at reduced levels, one seventy-five and one hundred and forty-seven. The reduced level at top of dam is 203 feet, top water level, 195 feet; lowest level to which water can be drawn off, 170 feet; the maximum width of the base of the dam at the ground level is 525 feet. The water slope is pitched with diorite blocks 18 inches deep. The puddle-wall is carried down from a distance of about six feet below the top of the bank to the solid shale and is eight feet wide at the top, battering one in eight outwards to ground level, and inwards below the ground level to the shale foundation; it is protected on each side with selected materials, consisting of red and white clay rammed in layers six inches deep sloping one in 12 downwards towards the puddle-wall. The remainder of the dam consists of similar materials sloping in a similar manner towards the puddle-wall but rammed in layers 12 inches deep.

The works for drawing water from the reservoir consist of a curved tunnel 932 feet long, driven through the solid ground altogether clear of the embankment; it is circular in form and 12 feet in diameter and is brick lined throughout. There is a stopping formed by building out the brickwork in stepped concentric rings, and filling up the space between them with concrete so as to prevent the water creeping along the outside of the tunnel. Two lines of cast-iron flanged pipes 48-inch in diameter are laid in the tunnel above referred to, which are continued through the inlet tower to the reservoir and into a basin at the outlet end, terminating in each case with a bell-shaped mouth, and having concentric rings cast on the lengths which pass through the brickwork of the tower. These pipes are also continued below the outlet tower to the scouring channel. The four feet pipes also extend to the bottom of the reservoir and can be used as syphons to empty the reservoir should it be necessary at any time to do so. In both the inlet and outlet towers are arranged the various stop valves and the machinery for raising and lowering them, which consists of screws driven by spur and bevel gearing. The valves in the inlet tower are arranged to draw the water from the reservoir at different levels. A lattice girder foot bridge of three spans on brick piers gives access to the inlet tower.

The canal below the Prospect Reservoir is four and three-quarter miles long, and the cross section is partly with vertical sides, and partly V shaped. The basin and part of the canal are lined with diorite ashlar masonry. The high water level of the reservoir end of the canal is 175·50 above sea level, the level of the top of the canal is the same

throughout the entire length of this section, viz. 177·5 feet, this arrangement allows an increased head to be obtained for the works nearer Sydney. Owing to the nature of the ground 900 feet of this section had to be covered in and is virtually a culvert under pressure. The fall in the canal is at the rate of 6 inches per mile. The water is conveyed over a valley at 44 miles by means of a brick aqueduct of 22 arches each 30 feet span. At the end of the canal there is a straining basin and pipe-head reservoir from which the water is conveyed through wrought-iron pipes six feet in diameter three-eighths and seven-sixteenths of an inch in thickness for a distance of four and seven-eighths of a mile, terminating in a screening chamber at Potts Hill. The capacity of the canal and six feet pipe from Prospect to Potts Hill, a distance of about nine and five-eighths of a mile, is 50 millions of gallons per day. Near this point a large balance or service reservoir is now being constructed. It will be 1300 feet in length and 900 feet in width, having a capacity of 96 million gallons. This reservoir will be constructed so as to admit of the water rising freely if necessary to the same height as the water at the commencement of the canal below Prospect, viz. 175·5 feet.

A branch pipe, fifteen inches in diameter, leads off the six feet pipes at the Dog Trap Road to supply Granville, Auburn and South Parramatta

From Potts Hill screening tank, two 30-inch pipes will start and supply the Northern, Western and Southern suburbs, one to be taken across the Parramatta River to Ryde, where there will be a pumping station to lift the water to a tank on the Lane Cove Road at Chatswood to supply the whole of North Shore. From the reservoir on Ryde Hill, the districts of Hunter's Hill and Gladesville will be supplied.

A 48-inch pipe carries the water from the screening chamber at Potts Hill as far as the branch to Petersham, a distance of $7\frac{1}{2}$ miles, from which point to Crown Street, a distance of $3\frac{3}{4}$ miles, the pipes are 42 inches in diameter.

The Petersham Reservoir holds two millions of gallons and is supplied by a 48-inch branch from the main 1200 yards long. The time required to fill the reservoir is two and five-sixths of an hour.

The Crown Street Reservoir, into which the 42-inch pipe discharges, is the one at present used for supplying Sydney. The top water level is 141 feet over H.W. Sydney, and the bottom is 125 feet. The capacity of this reservoir is about $3\frac{1}{4}$ million gallons; it is, however, contemplated to enlarge it to about $4\frac{1}{2}$ million gallons immediately. The pumps by which the upper levels of the town are supplied are at Crown Street.

The mean hydraulic gradient of the pipe from Potts Hill is one in 2907·111, and the pipe will discharge a volume of water equal to $17\frac{3}{4}$ million gallons daily.

About nine-tenths of the district of Sydney may be supplied by gravitation.

The following is a statement of the lengths of each description of work:—

	Miles
Tunnels	$11\frac{5}{8}$
Canals	33
Across Prospect Reservoir	2
Wrought-iron Flumes, 8-ft. and $7\frac{1}{2}$-ft. dia. ..	$\frac{1}{2}$
Wrought-iron Pipes, 6-ft. dia.	$4\frac{7}{8}$
Cast Iron Pipe, 4-ft. dia.	$7\frac{1}{2}$
Cast Iron Pipe, $3\frac{1}{2}$-ft. dia.	$3\frac{3}{4}$
Total length of conduit in miles ..	$63\frac{1}{4}$"

A bronze tablet placed on the outlet valve house at Prospect, in 1910, commemorates the association with the scheme of Edward Orpen Moriarty, M.Inst.C.E., who as Engineer-in-Chief for Harbours and Rivers, was responsible for the design and execution of the works described above.

REFERENCES

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Paper on Geelong and Sandhurst Water Supplies—W. Clark, Mr Homersham, Mr Moriarty. Vol. 56, Proc. Inst. Civil Engineers.

Report on proposed Kenny Hill Water Scheme: by E. O. Moriarty, Engineer-in-Chief, Harbours and Rivers, 1880-1881.

Description of Sydney Water Supply—Details of Nepean Tunnel, Cataract Tunnel—Aqueducts, Canals, Prospect Reservoir, etc., by Professor W. H. Warren. Proceedings of the Australian Association for the Advancement of Science, Vol. 1, 1888.

Parliamentary Standing Committee Report on Storage Reservoir at Potts Hill and second line of Pipes to Crown Street, 1888.

HUDSON'S TEMPORARY SCHEME, 1886-1888.

Showing section of timber fluming forming part of the temporary connection of the incomplete Upper Nepean Scheme with the Botany Water Supply. The No. 1 72″ Main which later formed the permanent connection at this point is shown alongside.

CHAPTER VII

HUDSON'S TEMPORARY SCHEME, 1886-1888

Before the Upper Nepean Scheme was completed, an emergency arose which made it necessary to bring the work done into use in order to supplement the Botany supply. The story of this effort, which was known as Hudson Bros.' Temporary Scheme, constitutes an epic in the history of Sydney's Water Supply.

About June, 1885, Sydney and its immediate suburbs were in very bad straits for domestic water; that wonderful sponge-like basin of the Lachlan and Botany Swamps (area 25 square miles) from which Sydney had for many years obtained its supply, varying from $2\frac{1}{2}$ to $6\frac{1}{4}$ million gallons per day, had, owing to the dry weather, practically given out, there being only about ten days' supply left. Sydney and surrounding suburbs had been placed upon an intermittent supply.

The Nepean Scheme, which had been started some four years before, and had up to that time cost over £1,250,000, was in an incomplete state, the Prospect dam only about half completed, and the Upper Canal in many parts still unconnected by pipes across the gullies. The Mayor and Aldermen of the City, who at that time controlled the water supply, appealed to the Government to provide some temporary relief. The Minister for Public Works (Colonel F. A. Wright), seized with the urgency of the matter, accepted, with the approval of his colleagues, an offer made by Hudson Bros. (then operating large engineering works at Clyde, the foundation of the Clyde Engineering Works of to-day), to bridge the gaps in the line of connection above the Lower Canal, and from the latter point by timber flumes and iron pipes, to deliver into the Botany Swamps not less than three million gallons of water per day. Against tremendous difficulties, this firm persevered with their undertaking, constructing 16 concrete dams in the Upper Canal, bridging eight creeks, and laying 1200 cast iron pipes, many of them four tons in weight, and by these means conveyed 300 million gallons of water into Prospect Reservoir; while from the Upper Canal by the 30-inch by-pass at foot of dam, they brought water into the Lower Canal. It was between the termination of the Lower Canal and Botany that their most serious difficulties were met with. First, two miles of timber fluming on timber trestles, in some places 70-ft. high, had to be constructed, delivering the water into a tank at the Dog Trap Road, Guildford; then three miles of 30-inch pipes carrying the water on to another tank at Potts Hill, then

by thin sheet iron pipes to Botany; 1000 tons of sheet iron were used, 700 tons of which had to be ordered by cable from England. Special machines, costing between £2000 and £3000, were designed and made at the Clyde Works for the manufacture of these pipes. When the water was turned on, the joints of the pipes were found to be defective, but these were soon remedied by the indomitable energy and skill of the brothers Hudson.

On 30th January, 1886, as Minister for Public Works, the Hon. Jacob Garrard, accompanied by the Mayor and Aldermen of the City, Members of Parliament and others, performed the ceremony of turning on the Nepean water into the Botany dams, thus augmenting the City supply by 3½ million gallons per day.

The *Sydney Morning Herald* of 1st February, 1886, in reporting the function, states:—"The new stream could be distinctly traced as it flowed into the water previously stored, and for a few days the supplies which will be sent into the City are sure to be discoloured by it. The real merit of the work consists in it having removed all danger of a water famine." The report further states:—"The Mayor of Sydney entertained the visitors at a picnic not far from the spot where the event took place, with unusual but very palatable fare, viz., hot juicy steak and potatoes boiled in their jackets; bush tea was also brought in addition to wines, but the new water was conspicuous by its absence." The various speakers paid a tribute to the undaunted enterprise and energy of Hudson Brothers, which had brought the project to such a speedy and successful issue.

A certain amount of criticism was levelled at the Government at the time for its action in accepting Hudson Brothers' offer without inviting tenders, but the emergency was so pressing that the Government had no difficulty in satisfying Parliament and the people that it was only by the prompt action taken in entrusting the work to this firm that the impending water famine could be staved off. It was pointed out that the preparation of plans and specifications to enable tenders to be called would have occupied some months, whereas the whole work was completed, at a cost of about £78,000, within about seven months from the time Hudson Brothers put their proposal before the Government.

In course of time the work was dismantled. Much of the fluming and piping was sold and other material was put to various uses in connection with later construction and maintenance works, municipal culverts and drains. Some of the 36-inch pipes used for crossing ravines were utilised in 1890 in laying a temporary rising main from Moore Park gates to Paddington Reservoir, until the permanent additional main was laid.

A picture of a section of the fluming erected on trestles is shown opposite page 62 alongside the original 72-inch main between Pipe Head, Guildford, and Potts Hill Reservoir.

STATISTICS RELATING TO WATER SUPPLY, SUMMARISING EXPANSION OF OPERATIONS OVER PERIODS 1888-1938

	1888	1908	1918	1928	1938
Storage Reservoirs:					
No. 1 Prospect					
„ 2 Manly					
„ 3 Wollongong — No. 1 Upper Cordeaux					
„ 4 Wollongong — No. 2 Upper Cordeaux					
„ 5 Cataract	1	3	5	7	8 (Manly not in use)
„ 6 Cordeaux					
„ 7 Avon					
„ 8 Nepean					
„ 9 Woronora (First Stage)					
Available capacity	5502 [a] m. galls	5742 [a] m. galls.	23,218 m. galls.	91,314 m. galls.	109,071 m. galls.
Service Reservoirs (in use):					
Number	5	30	58	63	80
Capacity	103½ m. gs.	148¼ m. gs.	170 m. gs.	365½ m. gs.	498 m. gs.
Pumping Stations (exclusive of minor or temporary boosters):					
Number	2	6	7	20	23
Quantity of water—					
(a) pumped to service reservoirs	1085 m. gs.	5498 m. gs.	8996 m. gs.	16,411 m. gs.	23,917 m. gs.
(b) boosted into trunk mains	—	—	4623 m. gs.	16,368 m. gs.	12,084 [b] m. gs.
Mileage of mains	355	1432	2554	3289	4235
Population supplied .. .	296,246	620,415	992,970	1,250,968	1,438,233
Number of buildings supplied	61,718	124,083	196,685	290,923	341,948
Quantity of water delivered into the distribution system	2973 m. gs.	8967 m. gs.	15,096 m. gs.	27,322 m. gs.	38,431 m. gs.
Average daily consumption	8·144 m. gs.	24·567 m. gs.	41·359 m. gs.	74·650 m. gs.	105,290 m. gs.
do. per capita consumption	27·29 galls.	39·59 galls.	41·63 galls.	51·32 galls.	73·21 galls.

[a] Prospect storage down to gravitation limit. Following the completion of Cataract Reservoir, storage available in Prospect Reservoir for supply purposes has been taken at 1951 million gallons, being the quantity which can be withdrawn without risk to stability of the earthen embankment.

[b] Pressure Tunnel, Potts Hill to Waterloo and Crown Street Pumping Stations in operation from Nov., 1935.

CHAPTER VIII

UPPER NEPEAN SCHEME—DEVELOPMENT SINCE 1888—GENERAL

During the fifty years that have passed since the completion of the original Upper Nepean Scheme, Sydney has grown into the third City of the British Empire, and the population served with water by the Metropolitan Water Board has increased from 296,000 to nearly 1,500,000 people. The consumption of water per head of population has also enormously increased, due to the wide extension of sewerage, the more general introduction of public baths and showers at surfing beaches, development of parks and municipal street gardens, and the growth of secondary industries using water in large quantities. These growths are illustrated in the graph opposite page 66, showing the population, total annual consumption, and consumption per head of population for each year.

The development of the water supply system in response to these changes has necessarily been great, and the main features of this development are set out in the statistical summary opposite. Although it has taken place piece by piece, each addition has been determined in its essentials by the original scheme. To follow these additions in their chronological order of sequence would be a long and tortuous process, and would not result in a clear picture of the system as it stands to-day. Consequently, in what follows the system has been dealt with in the various broad sections into which the works now group themselves. These are:—

(a) Head Works.
(b) The main distribution systems, comprising trunk mains and service reservoirs, pumping stations, suction and rising mains.
(c) Reticulation.

The distribution systems in their turn fall naturally into three divisions:—

(i) The southern system, serving the City of Sydney and the municipalities situated roughly between Parramatta River and Sydney Harbour on the north, and Botany Bay and Georges River on the south.

(ii) The northern system, serving the municipalities and shires on the northern side of Parramatta River and Sydney Harbour, extending to Palm Beach on the coast and Brooklyn on the northern railway line.

(iii) Country water supplies.

Before proceeding to these accounts, some reference to the rainfall, river gauging and evaporation records that have been accumulated over the catchment area should be made and a description given of the means taken to protect the stored water from contamination.

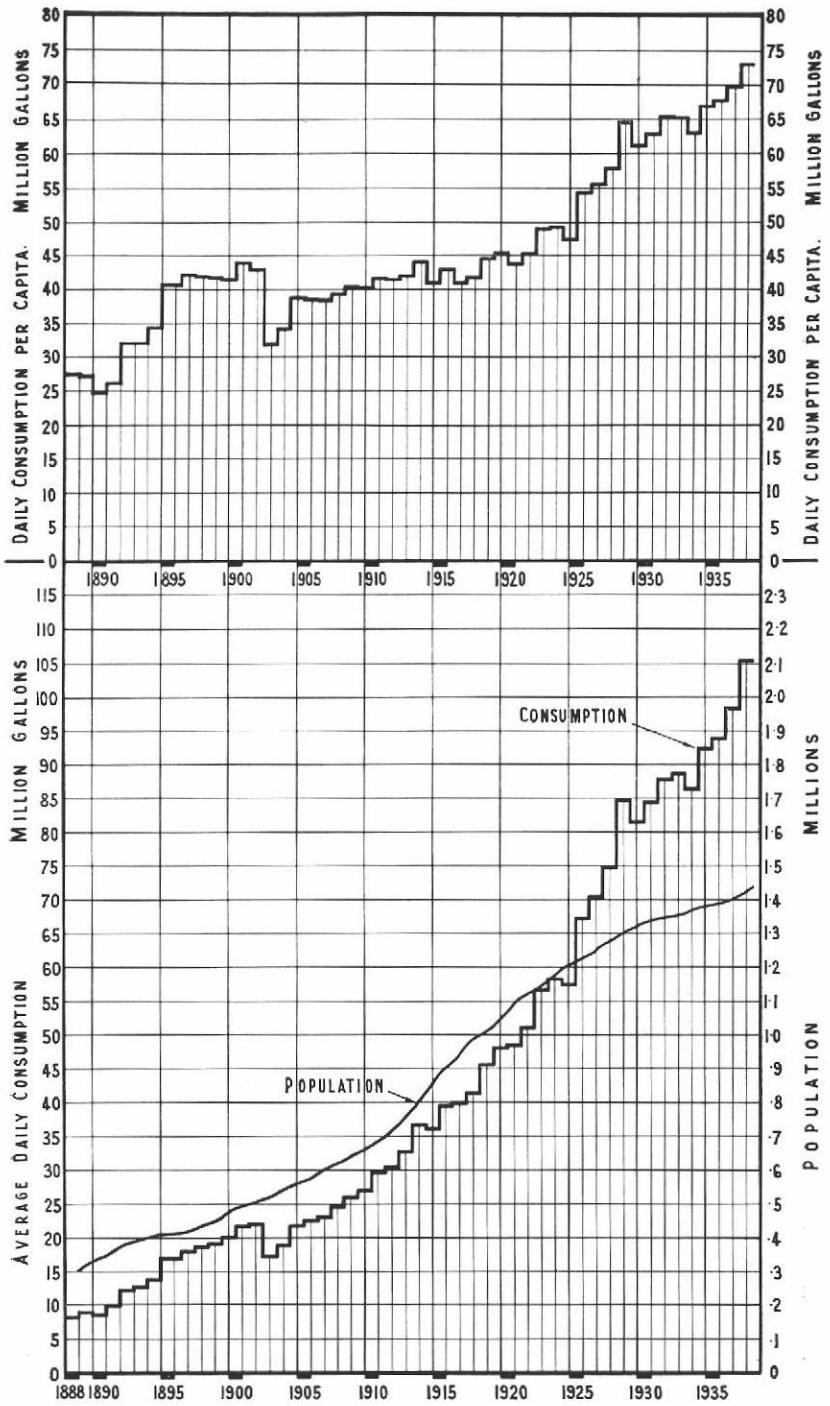
Rainfall and Runoff

Accurate records of rainfall, runoff and evaporation extending over long periods are necessary for the proper forecasting of what may be expected in the future and for determining the degree to which storage is economically warranted, either generally or at any particular site.

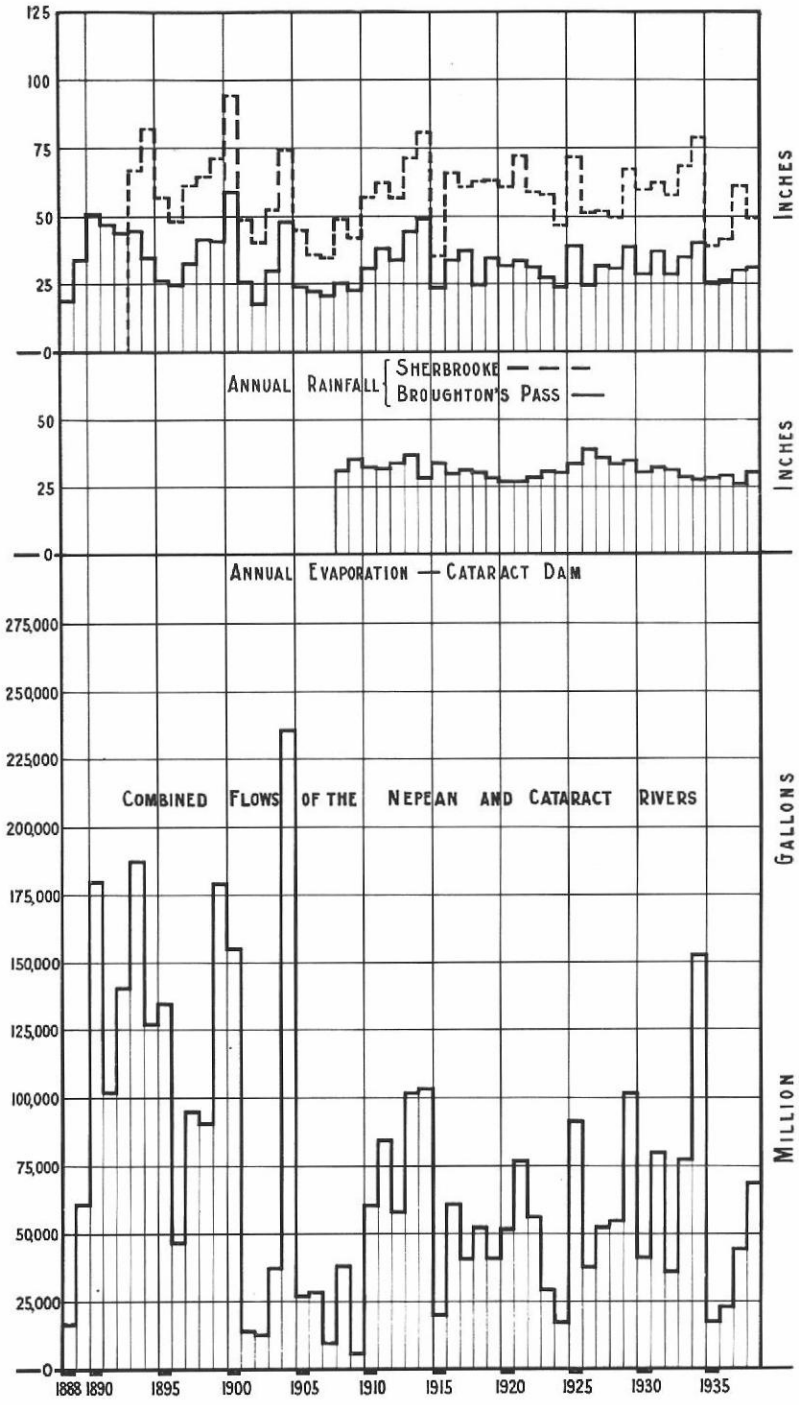
The earliest record of rainfall on the catchment area was made in 1869, when a rain gauge was established at Wilton not far from Pheasant's Nest. Records were taken at this station until 1876 only. In 1871, a gauge was established on the upper reaches of the Cordeaux River and readings were taken until 1924. In 1902, the Wilton station was re-established on a different site, and in 1928 the Cordeaux station was replaced by one some distance away. At both of these stations, readings have since been kept continuously.

A record of rainfall has been kept for Mittagong since 1886, Broughton's Pass since 1888, Robertson since 1890, Sherbrooke and Yerrinbool since 1892, and Cataract since 1894, while in 1907 seven stations on or near the Cataract and Cordeaux catchments were established. At present, readings are taken regularly at 23 stations on, or adjacent to, the Nepean catchment area.

The annual rainfall varies greatly at different points on the catchment, but the average fall is about 47 inches per annum. Rainfall by itself does not, however, give any indication of runoff, this being dependent to a large degree on the intensity of the fall at any time and the period over which any rain extends. It is a characteristic of the Upper Nepean catchment that the first two inches of any rain adds little to the volume of the stored water, being utilized largely in soaking the ground. If steady rain continues beyond this limit, a good runoff results. This was abundantly demonstrated during August, 1938, when, after a prolonged drought, rain commenced to fall on the 20th and continued until the 26th. During the first four days an average of 8 inches of rain fell and the storage increased by 10,000 million gallons. On the night of the 24th, however, 5½ inches of rain fell, and the volume of water stored increased by 22,500 gallons in 48 hours, i.e. a greater amount



POPULATION AND CONSUMPTION
1888 - 1938



RAINFALL, EVAPORATION AND RIVER FLOWS METROPOLITAN CATCHMENT AREA

than had been produced by the preceding four days' rain, although this latter was greater in the aggregate than fell on the 24th.

The proper gauging and recording of runoff are therefore of even greater importance than that of rainfall. For this purpose, in 1868, gauges were established on the Nepean River at Pheasant's Nest and on the Cataract River at Broughton's Pass, and the river flows have been measured with more or less accuracy ever since that year. Gaugings have also been made at other points on the catchment area to provide information for the design of dams.

In 1913, a Cippoletti gauging weir was constructed at Pheasant's Nest on the tunnel inlet, and in 1924 this was provided with an automatic recorder, while in 1923 a weir and recorder of similar types were established at Jordan's Crossing on the Cataract River, and at Pheasant's Nest, thus giving a more accurate and dependable record of flow.

Since 1919, the gauging of streams on the Nepean and other catchment areas has been carried out by officers of the Water Conservation and Irrigation Commission on behalf of the Board.

The recorded rainfall and runoff (river-flow) figures obtained since 1888 are illustrated in the graph opposite. The large variations thus indicated demonstrate the reasons for the extensive storage (described in chapter IX) which has had to be undertaken.

The impounding of large volumes of water and the exposing of large surfaces to the direct rays of the sun, make it necessary for evaporation records to be kept in order that accurate estimates of the losses that are likely from that source can be made. To this end, evaporation gauges were installed at Prospect in 1893, at Cataract in 1910, and at Avon in 1925. The results at Cataract are illustrated in the graph opposite. Broadly speaking, the evaporation averages about 31 inches per annum, i.e. somewhat less than the number of inches of average rainfall.

Protection of Catchment Area

Sydney is fortunate in that the catchment area of its water supply consists in the main of a comparatively clean type of country, which, on account of the sterility of the greater portion, has never attracted more than a scattered agricultural or pastoral occupation. Because of this, the water which runs off the area, after sedimentation while impounded in the storage dams, is found by continuous chemical analysis and biological examination to be of a standard of purity requiring no treatment or filtration. It is a major responsibility of the Board to keep it in this position, and to prevent any pollution of the catchment area.

Out of a total area of 347 square miles, or 222,080 acres, embraced in the catchment area, alienated holdings represented originally about 30,000 acres. Some of these holdings were in later years resumed in connection with the construction of the storage dams, being within the area which would be submerged, while others have been acquired by the Board in accordance with its policy of purchasing alienated lands situated in close proximity to stored water whenever a favourable opportunity occurred. Two notable instances of this might be mentioned. In 1921 the Board acquired two areas which were about to be offered in subdivision at Aylmerton and Yerrinbool on the southern railway line near Avon Dam, and in the same year, 657 acres on the eastern boundary of the catchment area near Bulli Lookout and Sublime Point were acquired with a view to keeping the large number of visitors to these resorts a further distance away from the headwaters of Cataract Dam.

The boundaries of the catchment area were originally gazetted on 7th July, 1880, when it had been definitely decided to go on with the construction of the Upper Nepean Scheme. The boundaries as gazetted were very faulty, including areas which were outside, and omitting areas which were inside, the drainage basins of the streams. It was not until 1922 that an Act was passed empowering the Governor to issue a Gazette proclamation re-defining the boundaries in accordance with an accurate survey made by the Lands Department.

It is a remarkable fact that the Acts under which the Board functioned from 1888 to 1924 gave it no statutory powers to effectively control the catchment area, and it was soon found necessary to obtain the co-operation of the Lands Department, Mines Department, Public Health Department, and later the Forestry Department, to meet as far as possible the difficulties the Board found itself in by this defect in its Act. In the early years an arrangement was made with the Lands Department to refer all applications for leases within the catchment area to the Board for any objection it might have to the granting of them, and the Mines Department agreed to similarly refer all applications for mining leases. The Board's attitude was one of consistent opposition to the granting of any mining leases or the establishment of any industry in the area which might in any way induce further settlement therein, and its wishes in this respect were generally complied with by the departments concerned.

For a few years after its inception, the Board, with the approval of the Minister for Lands, employed the forest ranger at Bowral as its inspector in the catchment area, but later it engaged its own ranger and in 1897 increased the number to two to enable every farm or other holding on the area to be visited once a month. In 1902, the Board's Medical Officer was placed in charge of the rangers, and they have since carried out their duties under his supervision.

In 1904, following a series of special visits to the more thickly settled portions of the catchment area by the Board, drastic measures were taken to provide for a more thorough method of supervision and inspection. The new Medical Officer and the inspector appointed under him, together with his assistant, found it necessary to take vigorous action to improve the sanitary condition of many of the holdings. This action met with much opposition from the settlers who formed Defence Associations, from which deputations to the Ministers of the Crown were arranged. Happily, the Board which, as before stated, was at this time entirely dependent on delegated powers of control of the area, was supported in its actions by the Ministerial heads of the departments concerned. The delegated powers under which the Board's rangers discharged their duties were derived from their appointment as:—

(a) Crown Lands Bailiffs under the Crown Lands Act, enabling them to deal with persons turning cattle on to Crown Lands in the catchment area without permits, or camping thereon.

(b) Persons authorised under the Public Health Act to enter private property, inspect premises and require action necessary to cure insanitary conditions.

(c) Persons authorised under the Forestry Act to deal with offences by timber-getters.

By these devious means the defects in the Board's Act were to an extent overcome, but obviously there was still room for the commission of many acts which might lead to contamination of the streams and feeders which the Board had no power to cope with effectively. Moreover, where there was any resistance to its requirements on the parts of settlers, the Board was dependent upon the Government Departments from which its rangers derived their authorities where legal action was necessary to enforce compliance with the notices served, and this did not always operate satisfactorily in practice. The existence of popular tourist resorts such as Bulli Pass, Sublime Point and Loddon Falls, the two former on the north-eastern boundary of and the latter just within the catchment area, rendered constant vigilance necessary by the rangers during week-ends and on public holidays. To help cope with the difficulty caused by the increasing number of motor cars conveying visitors to these resorts, the Board, in 1926, set aside an area of about nine acres at Bulli Lookout as a parking space under the control of the Bulli Shire Council, which body was required to carry out such drainage and other works as the Board considered necessary to prevent any pollution of the watershed. The large acreage of Crown Lands in the catchment area attracted numbers of blackberry pickers, rabbit-trappers, shooters, flower-gatherers, etc., and prior to the Act of 1924, the Board had no means of effectively coping with these people. The Crown Lands were

not vested in the Board, and it therefore had no power to enclose with fences portions which were convenient to centres of population.

In 1914 the deviation of the Great Southern railway between Picton and Mittagong entered the catchment area, and two railway stations were erected therein. Besides rendering constant supervision necessary of the railway workers' camps, this caused real estate operators to open up two subdivisions of private lands in the area, and the Board found it necessary, as previously stated, to buy them out and thus prevent the settlement which would have ensued from the disposal of the subdivisions. In 1926, the Port Kembla to Moss Vale railway was constructed through portion of the catchment area notwithstanding protest by the Board.

The passing of the Act of 1924 marks the beginning of the period from which the Board was able by the powers contained in its own statute to effectively control the catchment area and protect it from acts liable to lead to pollution of the water supply. This Act prohibits the sale or leasing of any Crown Lands within the catchment area, or the granting of any license relating thereto under the Crown Lands Act. It requires notice to be given to the Board of any proposed lease or licence relating to catchment area lands under the Forestry, Mining, Local Government, Public Health, Dairy Supervision, Cattle Slaughtering or noxious Trades Act, and if the Board objects, the matter is referred to the Minister for Public Works for settlement by the Governor. The Board is also empowered to make by-laws to control and regulate the sanitation of the catchment area, and the sanitation, use and occupation of premises therein so as to avoid insanitary conditions thereon or any interference therefrom with the purity of the water supply. To put it tersely, the Board is empowered to so regulate the conditions under which the people within the catchment area live and carry on their industries or occupations, as to eliminate practically any risk of contamination of the water supply from this source. They are furnished from time to time with copies of the Board's by-law setting out its requirements in this regard, which include the notification to the Board of the occurrence of any infectious diseases such as typhoid, dysentery or epidemic diarrhoea. A further provision gives the Board power to control and regulate or prevent picnicking, camping, shooting, fishing, or bathing in any dam or stream, flower gathering, or the parking of motor or other vehicles within the catchment area. Notices are plentifully displayed on trees along the boundaries, warning people against entering the area. Fences have been erected at the more frequented places between Bulli Lookout and Loddon Falls, to prevent indiscriminate picnicking on the area adjacent to the Main South Coast Road.

NEPEAN CATCHMENT AREA

REFERENCE

METROPOLITAN CATCHMENT AREA, boundary thus
(347¼ Square Miles)

PROTECTED REGIONS (See BY-LAW 84, Clause 12)
[PICNICKING &c. ALLOWED ONLY BY OBTAINING PERMIT IN WRITING FROM M.W.S.&D. BOARD]

PROHIBITED REGIONS (See BY-LAW 84, Clause 13)
[PICNICKING, CAMPING, FISHING &c. ABSOLUTELY PROHIBITED]

ROADS shewn thus ▪▪▪▪▪▪▪▪ are for Access to Storage Reservoirs and are NOT PUBLIC ROADS.

APPIN
to Camden
to Campbelltown
from Sydney
to Sydney
Mt. Douglas Park
to Prospect Reservoir
BROUGHTON PASS
CATARACT RIVER
CATARACT DAM
Back Creek
Cascade Cr.
Wallandoola
Ligard Cr.
LODDON FALLS
LODDON R.
from Picton
WILTON
PHEASANTS NEST PASS
CORDEAUX RIVER
CORDEAUX DAM
Creek
AVON RIVER
AVON DAM
NEPEAN DAM
from Picton
BARGO
YANDERRA
RAILWAY LINE
YERRINBOOL
BURKE RIVER
LITTLE BURKE R.
Navigation Creek
COLO VALE
AYLMERTON
BRAEMAR
SOUTHERN MAIN LINE
MITTAGONG
Gibraltar 2830ft.
BOWRAL
MITTAGONG RANGE
Glenquarry Cr.
LONDON
Doudles Folly Cr.
LITTLE RIVER
EAST KANGALOON
from Moss Vale
to Robertson
from Moss Vale
ROBERTSON
from Moss Vale
to Jamberoo
SONG BONG PASS
AVON R.
ILLAWARRA
MACQUARIE PASS
to Wollongong
RAILWAY RANGE
RIXONS PASS
BELLAMBI
BROKERS NOSE
BALGOWNIE (TOWNSHIP)
BALGOWNIE
CORRIMAL
Bellambi Pt
Bulli Pt
BULLI PASS
THIRROUL
THE LOOKOUT
AUSTINMER
SUBLIME PT
COLEDALE
WOMBARRA
SCARBOROUGH
TOWRADGI
PACIFIC OCEAN
Mt Keira 1539ft.
NORTH WOLLONGONG
WOLLONGONG HARBOR
Flagstaff Pt
WOLLONGONG
ILLAWARRA
WOLLONGONG No 1 DAM
WOLLONGONG No 2 DAM
PRIVATE
Mt Kembla 1752ft.
FIG TREE
TOM THUMB LAGOON
COAST
from Kiama
PORT KEMBLA
BIG Pt
Red Pt
SOUTH

SCALE
MILES 0 ¼ ½ 1 2 4 6 8 MILES

The present staff of rangers consists of one head ranger and three assistants. In addition to their authority as Board's rangers, they are special constables and rangers under the Wild Flowers and Native Plants Protection Act, 1927, and Birds' and Animals' Protection Act, 1918-1930.

There are seven seams of coal underlying a considerable portion of the catchment area which represent a potential source of national wealth. The approach of some of the underground workings to points adjacent to the stored water in the large reservoirs raises considerations which are of vital importance to the Sydney water supply, and also to the various coal mining interests and the State itself. The matter has therefore engaged the attention of the Board over a period of some years and with the co-operation of the Department of Mines, suitable action has been taken in connection with leases affecting the catchment area to provide for the pillars of coal not to be reduced or extracted where they are under stored water or within 3, 4 or 5 chains thereof as the Department may decide, measured horizontally from any point vertically below any portion of the stored water. The depth of the workings below the ground surface would be from 290 to 300 feet.

The mining of coal owned by a mining company under land resumed from the company or some other owner is governed by certain provisions of the Public Works Act, and the law generally relating to compensation, and may be set out as follows:—

> Where the mine workings will be under or within 40 yards of the boundary of the resumed land, the mine owner must give 30 days' notice to the Board before commencing to mine within this marginal area, and the Board may then treat with the owner with regard to compensation, if it considers that the safety of the stored water would be imperilled by the workings extending inside this limit. The compensation would not include coal which would ordinarily be left in pillars to give lateral support to the resumed land in its natural state, i.e. without the added weight of the stored water. If no such action is taken, then the mining company may mine under the stored water to the extent that ownership of the coal entitles it to and if operations carried out in the usual manner of mining in the district cause damage, the Board is not liable for damage to the mine nor is the company liable for damage to the reservoir.
>
> Outside the 40 yards margin the mining company extends the workings towards this margin at its own risk notwithstanding that the manner of working is in accordance with that usual in the district. If the company is prepared to take this risk but the Board desires it to keep farther away than the 40 yards margin, it would be

necessary for the Board to resume the extra land and treat with regard to compensation for the coal required to be left in the land.

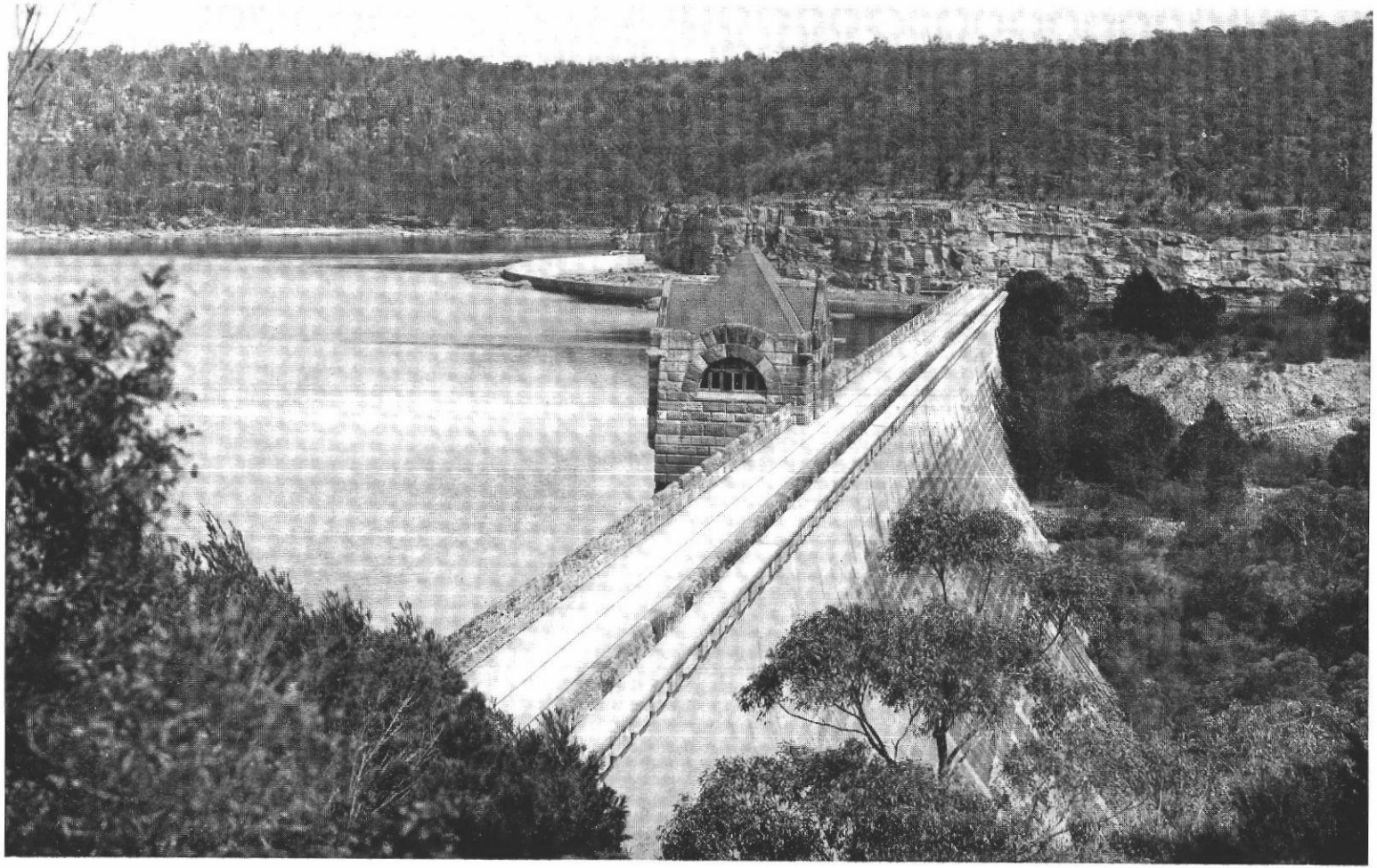
The location of mine workings from time to time within the catchment area has therefore to be watched in connection with safeguarding the stored water.

The following table gives the number and aggregate area of private holdings, their classification, and the number of persons permanently resident in the catchment area at different periods of time:—

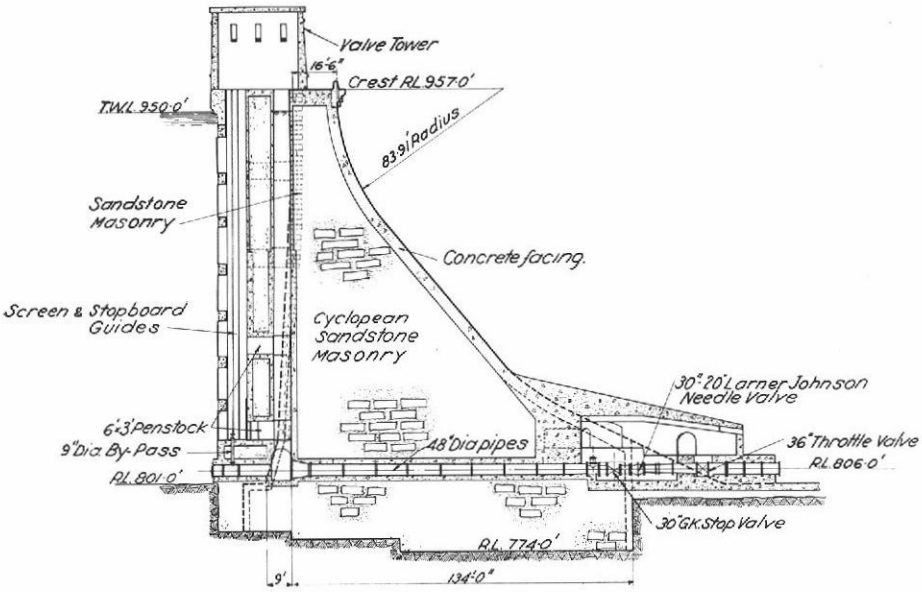
	1904	1914	1924	1938 Including Woronora Catchment
No. of Holdings	218	254	263	258
Area of Holdings	29,844 acres	27,696 acres	28,598 acres	33,486 acres
No. of Permanent Residents	918	1,345	2,786*	1,744
Classification of Holdings:				
Dairies	91	73	72	104
Farms and Orchards ..	40	26	34	39
Grazing areas	16	28	34	67
Residences	31	49	52	70
Railway Stations	—	—	2	4
Pig Farms	1	—	—	—
Poultry Farms	2	4	5	8
Factories	2	1	—	—
Sawmills	2	—	3	—
Business Premises	5	5	7	4
Schools and Colleges ..	7	7	7	7
Churches and Halls ..	1	4	4	3
Industrial Homes	—	3	3	3
Cemeteries	4	4	4	4
Camps	—	25	5	2
Mine Vent Shafts	1	3	6	6
Vacant	15	22	24	13
	218	254	262	334
No. of Cattle, Sheep, Horses, etc.	6,772	7,368	8,670	7,050

* Cordeaux and Avon Dams construction townships in existence.

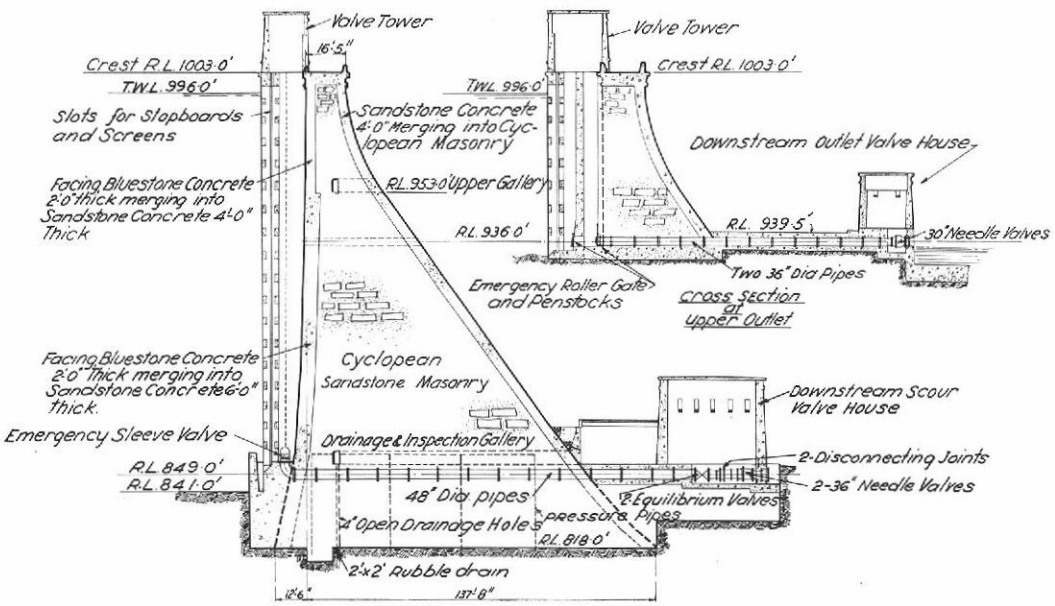
The principal village settlements in the catchment area are Lower Mittagong, East and West Kangaloon, Glenquarry, and Mount Murray.



CATARACT DAM.

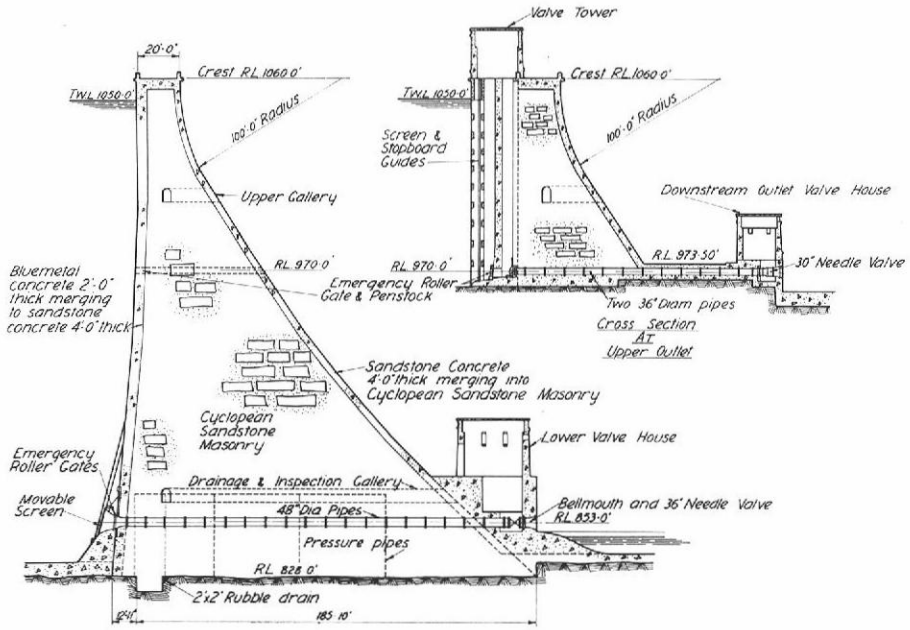


CATARACT

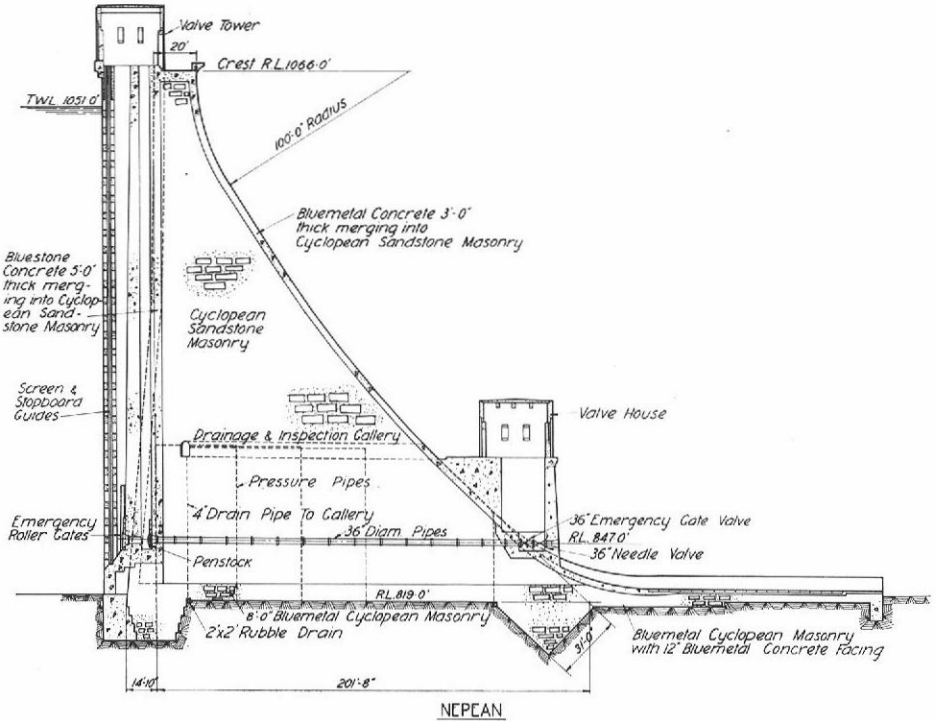


CORDEAUX

CROSS SECTIONS OF DAMS.

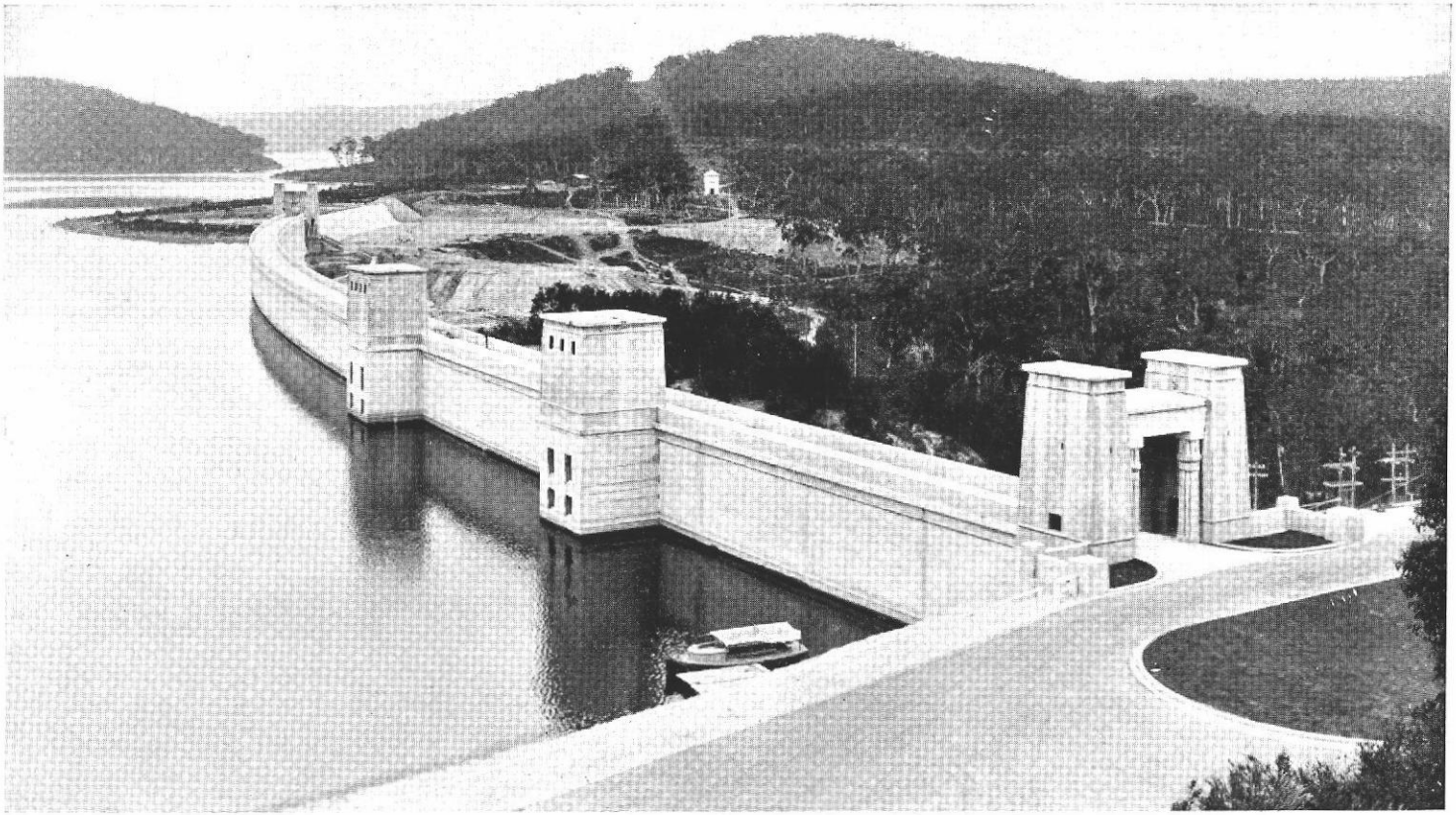


AVON



NEPEAN

CROSS SECTIONS OF DAMS.



CORDEAUX DAM.

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CHAPTER IX

UPPER NEPEAN SCHEME—DEVELOPMENT SINCE 1888

Head Works

Undoubtedly the most outstanding feature of the development referred to in Chapter VIII is the construction of four large storage reservoirs on the Rivers (Cataract, Cordeaux, Avon, and Nepean), whose waters were, under the initial scheme, merely diverted. This possibility, it had been pointed out, was forecast in the report of the Commission of 1867, and providing, as it did, opportunity for progressive development with increasing demand, was one of the essential merits of the Upper Nepean Scheme.

The original scheme was estimated to meet all requirements until the population to be supplied reached 540,000. By 1902, the population supplied was 523,000, and the forecast of the Commission had been proved correct.

At the latter end of 1901, a very severe drought set in, with the result that the water level in Prospect, which had been overflowing on 12th November, 1901, consistently dropped until at the beginning of June, 1902, the limit of the gravitation flow from the reservoir was reached. Meanwhile a pumping plant had been hurriedly purchased and erected to raise water from below gravitation level and discharge it into the lower canal, while two other proposals for the lifting of water from the Nepean River into the Upper Canal were also put in hand. The plant installed at Prospect consisted of nine centrifugal pumps arranged in duplicate. The principal unit (five pumps) had a capacity of from 25 to 33 million gallons per day at a 30-ft. lift, and the other unit (four pumps) was capable of raising 20 to 22 million gallons per day at a similar lift. (The average daily consumption at that time was 22 million gallons.) The pumps remained in operation from 9th June to 10th November, 1902, when rainfall caused an inflow which raised the level in Prospect slightly above the gravitation limit. The pumps were then stopped and the good rainfall which succeeded maintaining a satisfactory level in the reservoir, they were not again required. The complete installation cost £11,823. The plant was kept in efficient working order until Cataract Dam contained a satisfactory storage. It was dismantled about 1909.

The two other emergency schemes previously mentioned, which involved the establishment of pumping stations at Menangle and Penrith respectively, never actually came into use, although the former was completed (at a cost of £17,662), and all the plant and pipes for the latter had been ordered. After the rains had fallen in such measure as to put all question of an immediate shortage beyond doubt, they were dismantled and the plant, etc. transferred for use elsewhere.

The drought of 1901-1902 was the first of any severity experienced by the Board since its inception, and it brought the Metropolis perilously close to a complete water famine, closer than it has ever been since and it is hoped ever likely to be in future. Rigorous restrictions had to be imposed on the use of water for other than domestic and trade purposes, the use of garden hoses being banned and even watering by use of watering-can or other receptacle being prohibited in the later stages of the drought.

The seriousness of the position moved the Government to appoint in March, 1902, a Royal Commission consisting of:—

Joseph Davis, Esq., M.Inst.C.E., Under Secretary for Public Works.
Henry Deane, Esq., M.A., M.Inst.C.E., Engineer-in-Chief, Railway and Tramway Construction, Dept. Public Works.
W. J. Hanna, Esq., Commissioner for Roads and Principal Engineer for Roads and Bridges, Dept. Public Works.
Thomas Hughes, Esq., J.P., Mayor of Sydney.
T. W. Keele, Esq., M.Inst.C.E., Principal Engineer, Harbours and Rivers Branch, Dept. Public Works.
E. W. Knox, Esq.
W. L. Vernon, Esq., F.R.I.B.A., Government Architect.
L. A. B. Wade, Esq., M.Inst.C.E., Principal Engineer, Water Supply and Drainage,

and later in 1902, the following were added to the personnel of the Commission:—

Hon. Jacob Garrard, President, Metropolitan Board of Water Supply and Sewerage.
J. B. Johnston, Esq., President, Sydney Chamber of Commerce.
J. F. Smith, Esq., M.P.
J. P. Wright, Esq., President, N.S.W. Chamber of Manufacturers.
J. P. Josephson, Esq., A.M.Inst.C.E.,

to enquire into and report on the Sydney water supply system. Prior to this, the Board had itself, as its annual report for 1898-1899 indicates, instructed its rangers "to report as to any suitable sites on the upper reaches of the rivers for impounding water."

Cataract Dam

The main recommendation of the Commission was that a storage dam should be constructed at a point a little below the junction of

Cataract Creek with Cataract River. This site was selected as the result of joint investigations and surveys by the staffs of the Public Works Department and the Board. A majority report of the Commission recommended the construction of a dam about 120-ft. high to impound 7000 million gallons, at an estimated cost of £126,000.

A minority report, while concurring that the storage before-mentioned would be sufficient for immediate requirements, recommended that the dam be constructed of such section as would admit of its being raised at some future date so as to impound 18,200 million gallons, at an ultimate estimated cost of £217,500. The immediate cost of impounding 7000 million gallons with the increased section was estimated at £186,000.

The Act authorising the construction of the dam was passed by the Legislature in 1902, and provided for a wall 160-ft. high (from foundation level, i.e., 150-ft. from the river bed) with a storage capacity of about 18,200 million gallons. By June, 1903, much of the area that would be submerged had been cleared of timber and by the end of that year the foundation excavations were in progress.

In 1905, the work, which was let by contract to Messrs Lane and Peters, was fairly under way, the contract time for completion being two years. In the meantime, it was ascertained that a dam 160-ft. high would store 21,411 million gallons, and the Minister for Public Works (the Hon. C. A. Lee) under whom, as constructing authority, the work was being carried out, actuated by motives of what he believed to be economy, directed that the dam wall be reduced in height by 5-ft. with consequent reduction in storage from 21,411 to 18,600 million gallons. The Board, however, acting upon the advice of its President (Mr. T. W. Keele, M.Inst.C.E.), urged upon the Minister the desirability of building the dam to the full height set forth in the Constructing Act, and its attitude receiving support from the various constituent municipalities, the question was referred to a Royal Commission consisting of Mr Stuart Murray, M.Inst.C.E., Chief Engineer for Water Supply, Victoria, as President, Mr E. M. de Burgh, M.Inst.C.E., representing the Public Works Department, and Mr C. W. Smith, M.Inst.C.E., representing the Board.

The Commission, after a very full investigation, unanimously recommended that "the dam be built to the height of 150-ft. from the level of the natural surface of the river bed, at site, to the sill of the waste weir, giving a capacity at full supply level of 21,411 million gallons or thereabouts." The work was accordingly proceeded with on this basis, being completed about the end of 1907, and formally transferred to the Board on 10th June, 1908.

The dam, a cross-section of which is shown in plan opposite page 73, is built of cyclopean masonry, composed of large sandstone blocks quar-

ried at the site, weighing from 2 to 4½ tons, bedded in cement mortar, with the vertical joints filled with basalt or sandstone concrete. The upstream face consists of basalt concrete moulded blocks set in cement mortar. The downstream face is of basalt concrete, 6-ft. thick in the lower and 3-ft. thick in the upper levels. There are four lines of 48-in. pipes through the dam, but two only have been retained as permanent outlets for supply. In 1913, controlling valves and venturi meters were installed at the outlets, with the object of enabling the discharge to be more exactly regulated to the quantity required from time to time. The meters did not function well and were later removed. The total cost of the completed work, as handed over by the Public Works Department to the Board, was £329,136.

In 1909, official quarters were erected (in stone) to enable the staff to control efficiently traffic visiting the dam, and with the assistance of the Director of the Botanic Gardens, the grounds surrounding these and in the vicinity of the dam were suitably laid out and planted with trees. Cottages, also of stone, were likewise built to replace the structures erected during construction operations and temporarily occupied by the maintenance employees. The dam and its surroundings now constitute one of the show places of Sydney's water supply system, and have for many years attracted large numbers of visitors.

The dam was filled to capacity for the first time on 13th January, 1911, when the advisability of widening the spillway to avoid risk of a flood overtopping the wall was demonstrated. This work was accordingly carried out and completed in 1915.

Cordeaux Dam

The rainfall on the catchment area from the time of the completion of Cataract Dam until January, 1911, when it was first filled by heavy storms, had been abnormally low. The necessity for the early provision of additional storage thus became apparent soon after the completion of this work.

Accordingly, the Board, in 1911, caused a site to be selected on the Cordeaux River, and a gauging weir constructed. This was followed by the preparation of preliminary plans and estimates and the testing of the foundations, after which further investigation was taken over by the Public Works Department.

The succeeding years were characterised generally by good rainfall, and Cataract Dam maintaining a satisfactory level excepting for a dry period in 1915-16 when the water level receded over 37-ft., and the Great War (1914-1918) intervening, the construction of Cordeaux Dam did not commence in earnest until 1918. In that year, a Special Board was appointed by the Government "to enquire into the amplification of the Sydney water supply," and it was upon the recommendation of this

body as approved by the Public Works Committee of the New South Wales Parliament, that not only Cordeaux, but also Avon and Nepean Dams were proceeded with in turn. The personnel of this Board was formed by representative engineers from the Public Works Department (as the constructing authority), viz., Mr A. E. Cutler, M.Inst.C.E., M.M.I.E., Chief Engineer for Public Works and President of the Hunter District Water Supply and Sewerage Board, and Mr E. M. de Burgh, M.Inst.C.E., Chief Engineer for Water Supply and Sewerage; the Water Board (as the administrative authority), viz., Mr W. J. Millner, Assoc. M.Inst.C.E., President, Mr J. M. Smail, M.Inst.C.E., Engineer-in-Chief; the Water Conservation and Irrigation Commission, viz., Mr H. H. Dare, M.E., M.Inst.C.E., Commissioner; the Sydney Harbour Trust, viz., Mr T. W. Keele, M.Inst.C.E., Commissioner; with the Under-Secretary for Public Works (Mr T. B. Cooper) as Chairman.

Cordeaux Dam was completed in 1926 and was handed over to the Board by the Minister for Public Works on 3rd February, 1927, at a ceremony performed by His Excellency the Governor, Admiral Sir Dudley de Chair, K.C.B., M.V.O., R.N., in the presence of representatives from all the metropolitan municipalities and shires.

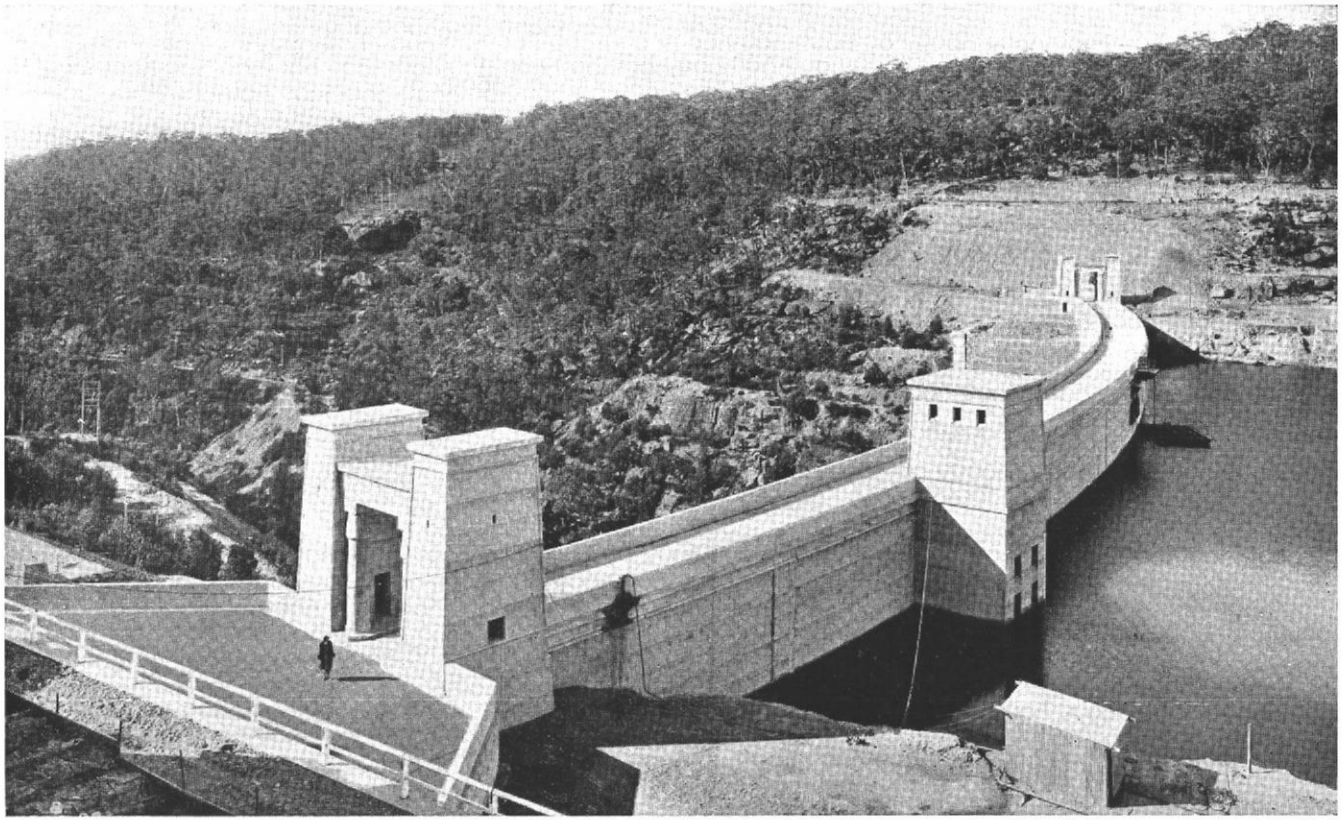
The dam is arched in plan, and is, in the main, composed of cyclopean masonry consisting of large blocks of sandstone quarried from the site, embedded in and packed in the joints with sandstone concrete. The upstream face consists of bluestone concrete 2-ft. thick, merging into sandstone concrete 6-ft. thick at lower levels and 4-ft. thick at higher levels. The downstream face is sandstone concrete, 4-ft. thick.

Cordeaux Dam embodies improvements in design and construction on the earlier constructed Cataract Dam. Contraction joints between units of construction were placed at intervals of 90-ft.; inspection galleries at upper and lower levels were also provided together with piping for registering any ground water pressure, while discharge outlets were arranged at two levels—an upper and a lower. The upper outlet consists of two 48-in. pipes fitted with 36-in. needle valves, and the lower of two 36-in. pipes with 30-in. needle valves.

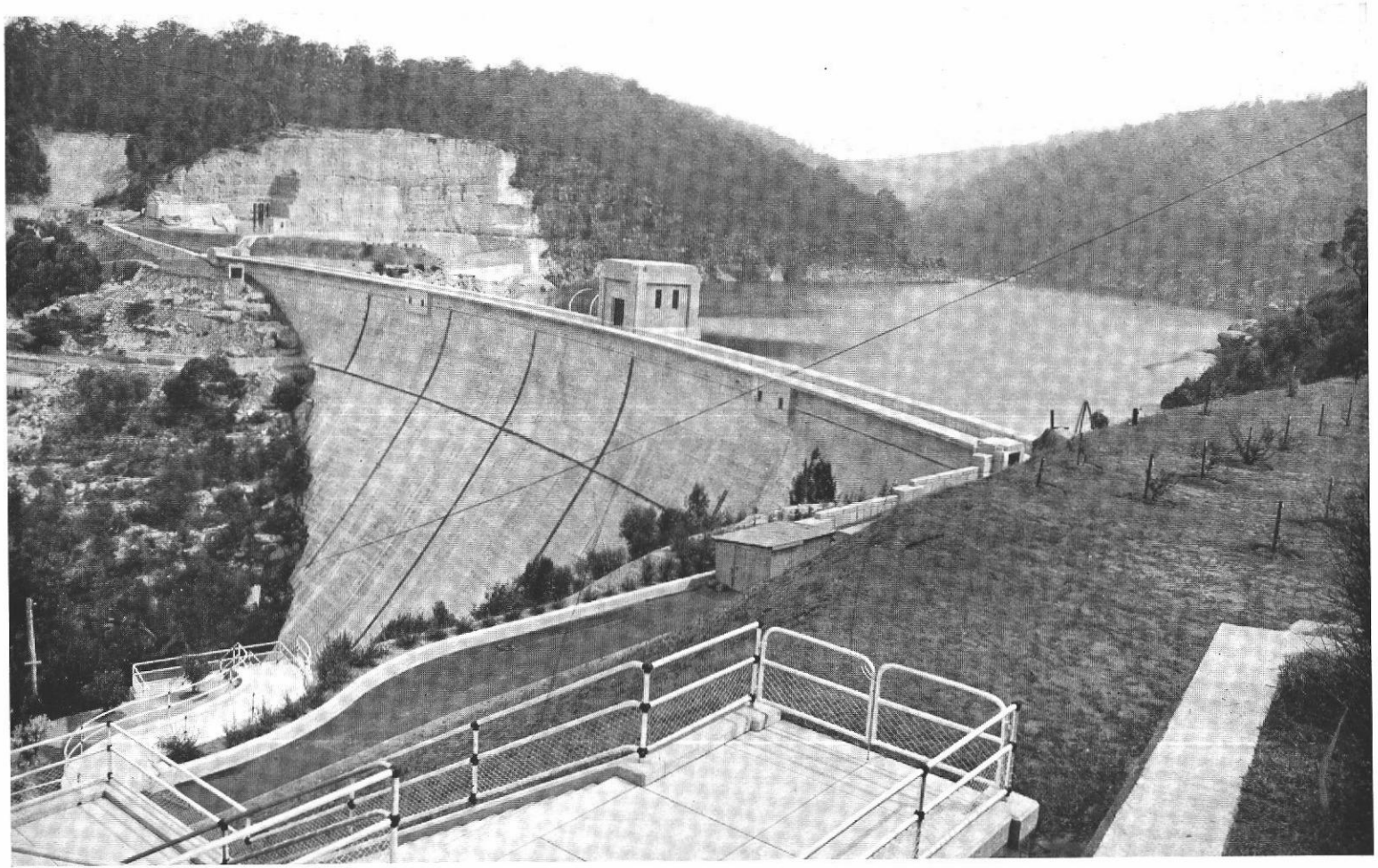
This reservoir is now largely reserved for supplying water to the South Coast District.

Avon Dam

In 1921, three years after the construction of Cordeaux Dam was commenced, and five years prior to its completion, a start was made by the Public Works Department with the construction of a third and much higher dam at a site selected on the Avon River, a tributary of the Upper Nepean. The Special Board having pointed out the urgency of additional storage to ensure adequate provision for a reasonable period ahead,



AVON DAM.



NEPEAN DAM.

its completion was accordingly hastened, and followed shortly after that of the Cordeaux dam in 1926. It was transferred to the Board on 20th January, 1928.

The dam is arched in plan, and its main construction is of cyclopean masonry, consisting of large blocks of sandstone quarried at the site embedded in and packed in the joints with sandstone concrete. The upstream face consists of bluestone concrete 2-ft. thick, merging into sandstone concrete 4-ft. thick. The downstream face is sandstone concrete, 4-ft. thick. It embodies the same improvements as Cordeaux, viz., inspection galleries at upper and lower levels with provision of piping to register ground water pressure, and upper and lower level discharge outlets.

The water discharges into a stilling pool before tumbling over the rocks as a waterfall into the bed of the river.

Until 1938, the lower outlets, which were controlled by single valves, had not been operated. The drought conditions which prevailed on the catchment area from August, 1934, to August, 1938, made it imperative that these should be available for use. Accordingly, additional needle valves were fitted to them, thus duplicating control, and the original valves opened in July, 1938. The lower outlets are therefore now available for use under any conditions.

Nepean Dam

While the Cordeaux and Avon dams were in the last stages of completion, a commencement was made, in 1925, in accordance with the recommendations of the Special Board of Reference, with a fourth dam. The site chosen was on the Nepean River, about $7\frac{3}{4}$ miles above the point where the Cordeaux River junctions with the main stream at Pheasant's Nest Pass, and about 4 miles by road south-east of Bargo railway station, 64 miles from Sydney. Construction was carried on by the Public Works Department until 1st September, 1928, when, under the terms of the Reconstitution Act of 1924, the work was transferred to the Board for completion. At that date, excavation for the foundations of the wall was complete and placing of concrete about to be commenced. Shortly after transfer, it was decided, in accordance with the recommendation of the then Chief Engineer to the Board (Mr G. Haskins, M.Inst.C.E., under whom, as Deputy Chief Engineer for Water Supply, Public Works Department, the work had previously proceeded) to increase the height of the wall by 25-ft., thereby adding nearly 50 per cent to the storage (from 12,566 million gallons to approximately 18,000 million gallons). The work, other than the clearing up and laying out the approach area and the disposal of the township, which were carried out later, was completed in 1935. The extended period of construction

(10 years) was largely due to the general financial depression which affected the whole Commonwealth during 1931 and 1932, and which resulted in the Board being compelled to curtail construction operations on 10th March, 1930, and to suspend work completely on 27th March, 1931, until, with the passing of the depression, it was able to resume operations on 12th June, 1933, after which work was carried on uninterruptedly to completion.

The dam is arched. The body of the wall is of cyclopean masonry, consisting of large blocks of sandstone quarried at the site embedded in and surrounded with sandstone concrete. To ensure watertightness all construction joints were grouted. The upstream face consists of blue metal concrete 5-ft. thick, the downstream face being of similar concrete 3-ft. thick. The Nepean dam embodies all the latest improvements in dam design and construction, and can be said, without hesitation, to be unsurpassed by anything of its kind in the Commonwealth, or for that matter, anywhere else. Its accurate line and finish are particularly pleasing, and it is destined, when the ground improvements about it have reached maturity, to be one of the show places of the Board. Inspection galleries are provided with pressure and drainage pipes from foundations and rubble porous drains led into same. Provision has also been made for any leakage of water past the copper seals in the contraction joints to be conducted into the galleries and drained therefrom. To facilitate the operations of the maintenance staff, an electric lift has been provided in the wall. The water is discharged through two 36-inch diameter outlet pipes, controlled by two 36-inch Glenfield-Kennedy needle valves.

Although the dam was ready to receive storage on 12th September, 1935, the rainfall on its catchment until August, 1938, was such that prior to that month, the maximum volume of water stored amounted to only 3,962 million gallons. Copious rains which fell from 20th-26th August, 1938, increased the storage to 14,130 million gallons, and further heavy rainfall towards the end of October resulted in the dam overflowing on the 27th October.

The Nepean reservoir has a small storage capacity relatively to its large catchment area, as may be judged from the fact that while its capacity is much the same as that of Cataract and Cordeaux, its catchment area is $2\frac{1}{2}$ times as great as the former and $3\frac{1}{2}$ times that of the latter. It will, therefore, under normal conditions, be more freely drawn from than the other dams to meet the requirements of the daily metropolitan consumption.

A summary of the dimensions and other statistical information relating to the four large storage dams is as follows:—

	Cataract	Cordeaux	Avon	Nepean
1. Commenced—Year ..	1902	1918	1921	1926
2. Completed—Year ..	1907	1926	1927	1935
3. Completed Cost—£ .	427,563	962,393	1,100,569	1,462,715
4. Storage Capacity—Million Gallons ..	20,743	20,597	47,153	17,898
5. Height of Wall from foundations—ft. ..	187	182	230	250.5
6. Length, including Pylons—ft.	811	1,327	728	700
7. Length of By-wash—ft.	684.5	500	437.5	436
8. Masonry in wall and spillway—cu. yds. ..	148,000	218,400	221,585	309,843
9. Catchment—sq. miles	50	35	55	123
10. Average annual rainfall over Catchment—inches	52	48	45	44
11. Annual inflow assuming 25 per cent run-off (considered a fair average based on experience)—million gallons ..	9,450	6,100	9,000	19,500
12. Lake area at Full Supply Level—acres	2,104	1,981	2,609	881
13. Average annual evaporation from full reservoir — million gallons	1,860	1,710	2,300	778
14. Full Supply Level above Sea Level—ft.	950	996	1,050	1,051
15. Crest Level above Sea Level—ft.	957	1,003	1,060	1,069.5
16. Greatest depth of water—ft.	150	170	210	225
17. Safe draught—million day gallons (with allowance for reserve)	22	17	28	21

It will be seen from the above figures that the four dams completely control the run-off from 263 square miles out of a total of 347 square miles comprising the Nepean catchment area. The remaining 84 square miles are partially controlled by the diversion weirs previously described,

situate on the Nepean and Cataract Rivers some miles below the dams, up to a limit of 150 million gallons per day (the capacity of the canal to Prospect). These works, therefore, may be considered to represent the limit of economical control of the Nepean catchment area under existing conditions and for many years to come.

The construction of these large works in positions remote from any settlement, necessitating the accommodation of several hundred men within the catchment area, involved the creation in each case of a model township, with sanitary arrangements of the most complete and efficient nature to guard against any possibility of pollution of the water supply, and to promote the health of the community. Paved streets were laid out, kerbed and guttered with proper drainage provision. Standard cottages were built for rental by married employees, single men being accommodated in barracks. Restaurants and business sites were provided and let out to approved tenants. A public school and an amusement hall were erected in each township, while a resident Medical Officer, nurse, and fully equipped motor ambulance rendered the requisite medical attention to all inhabitants, small contributions being levied from each towards the cost. On completion of each work, the townships disappeared, all structures being sold for demolition and removal, except those retained in connection with the maintenance of the dams.

Compensation Weirs—Nepean River

Following the completion of Cataract Dam, compensation weirs were built (by the Public Works Department) at nine selected points on the Nepean River, between Menangle and Wallacia, in order to safeguard the riparian rights of landowners affected by the interception of the flow of the river. These were subsequently transferred to the Board for control and maintenance as part of the water supply system.

Standards of Storage Provision

The amount of storage required to deal with the demands of any large aggregation of people is dependant upon—

(a) the quantity of water necessary day by day to satisfy their requirements, and
(b) the degree to which, and the periods for which, natural stream supplies that can be tapped fall below (a).

So far as Sydney is concerned, there are no streams which can be relied upon to give a perennial supply without storage, and it has been necessary to lay down certain standards against which the provision for storage at any time can be measured and determined upon.

WATER STORAGE AND CONSUMPTION

The statistics set out in the table which follows show the seasonal fluctuations in the available storage in the Cataract, Cordeaux, Avon and Nepean Dams, and the extent to which the gain from rainfall has met the draw-off from them to supply the Metropolis. Other details as to consumption and loss by evaporation are furnished in an endeavour to make the table a complete picture of co-related important phases of the water supply to Sydney and suburbs.

Year	Storage available at main dams in million gallons			Gain or loss of storage for the year in million gallons		Loss by Evaporation in million gallons	Water drawn from Storage Dams for year in million gallons	Maximum day's consumption in million gallons		Minimum day's consumption in million gallons		Average daily consumption in million gallons
	At 1st Nov.	At 31st March	At 30th June	Gain	Loss			Quantity	Date	Quantity	Date	
1927-28	66,598	66,709	74,537		930	3,699	22,328	104	31st Oct.	48	3rd Oct.	74.6
1928-29	76,279	81,457	82,246	7,709		4,772	17,002	143	9th Jan.	52	11th May	84.6
1929-30	88,493	77,533	88,493	6,247		4,629	17,627	139	9th Dec.	51	28th July	81.4
1930-31	83,163	72,735	86,772		1,721	4,480	18,632	140	23rd Dec.	51	5th July	84.4
1931-32	86,077	81,587	76,972		9,800	4,366	21,103	143	22nd Jan.	52	6th July	88.0
1932-33	85,698	83,976	87,881	10,909		4,313	20,370	142	12th Jan.	50	20th May	88.6
1933-34	86,371	88,108	88,493	612		4,094	12,364	149	24th Jan.	53	1st Oct.	86.4
1934-35	86,958	81,025	74,806		13,687	4,228	22,465	142	5th Feb.	52	28th July	92.2
1935-36	65,241	60,432	61,033*		13,773	3,564	31,889	139	27th Nov.	46	1st March	93.9
1936-37	50,575	49,977	56,350		4,683	3,251	35,405	142	5th Nov.	57	26th Dec.	98.6
1937-38	54,182	43,586	39,449		16,901	3,231	34,698	167	10th Jan.	63	3rd July	105.3

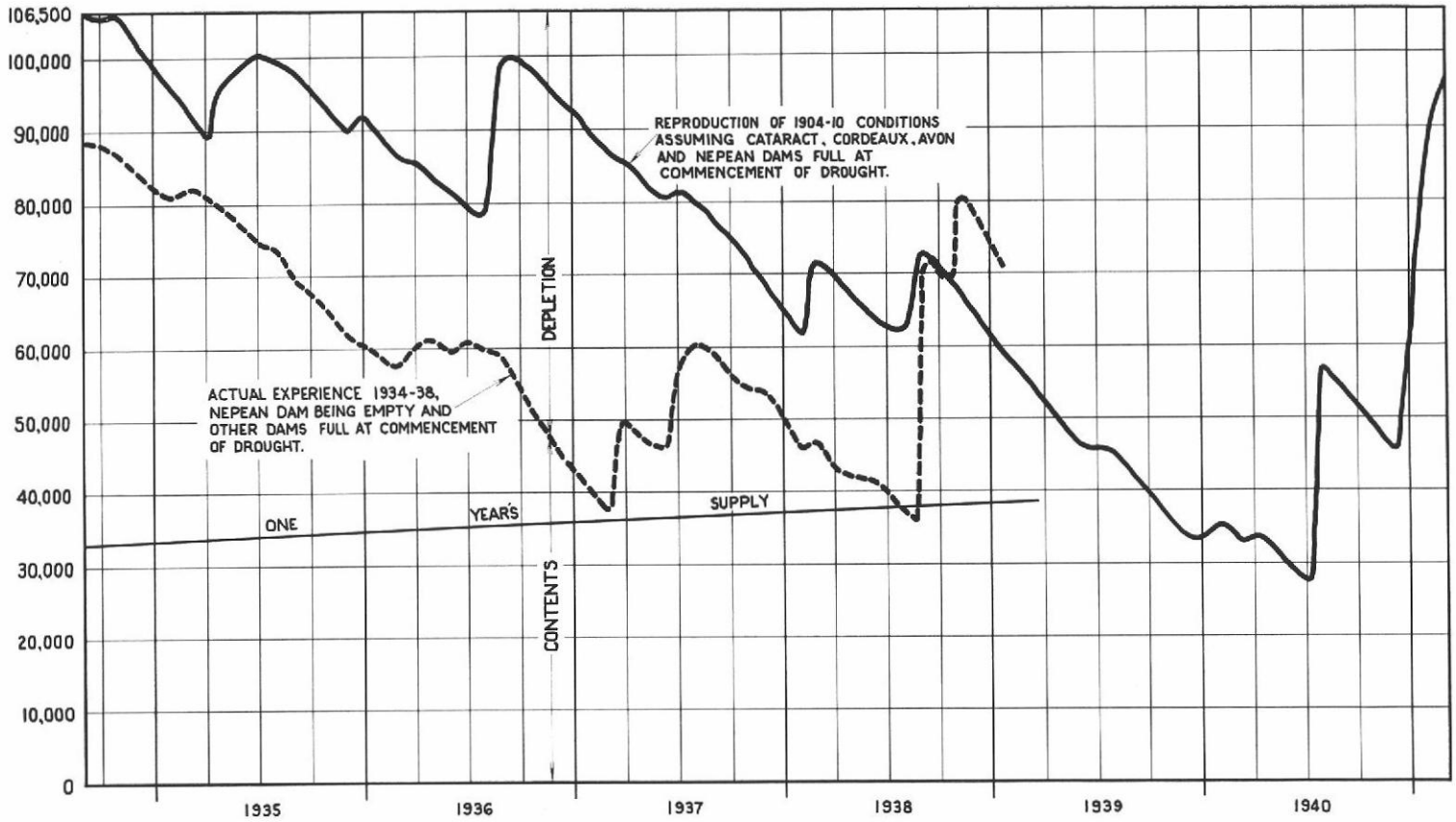
* Nepean Dam first included.

The Special Board of Reference, mentioned in Chapter IX, adopted as the basis for its recommendations the behaviour of the catchment area during the worst drought period that occurred in the years since 1871, for which rainfall or runoff records were available, viz., the period from 1904 to 1910. In its earlier reports a reserve was provided for at the end of a drought of similar duration, but later calculations were based on the principle that all existing major storages being assumed to be full at the commencement of any future drought, the capacity of the storages provided should be sufficient to supply the estimated successive annual requirements of the Sydney water supply over a period just corresponding to that of the 1904-1910 drought, due allowance being made for such runoff into the reservoirs as would have occurred during the 1904-1910 period, had the existing storages been constructed in 1904.

As a result of a careful analysis of the position, the Engineer-in-Chief (Mr S. T. Farnsworth) recommended to the Board, in a report dated 22nd June, 1938, that "storage provision should for the future be on the basis that Sydney water supply should be able to withstand a drought similar in intensity and duration to that of the six-year record drought, 1904-1910, and at the end of such drought have sufficient storage in reserve to withstand twelve months' further drought equal in severity to the year of lowest recorded runoff during such six-year drought." He pointed out that the earlier standard did not allow any margin of safety to deal with a drought more severe than the record of 1904-1910, and that the new standard was actually that for which several members of the Special Board of Reference had indicated their preference, but to which effect had not always been given.

The Board unanimously adopted the Engineer-in-Chief's recommendation, which is the basis upon which all future action will be taken, unless and until a greater drought than that of the 1904-1910 eventuates and shows the need for modification. It is clear, that any modification that will be necessary in the future will not be of a major character.

The need for resolute adherence to a definite standard of storage capacity, based on a long range view, irrespective of the favourable conditions that may prevail at any particular period, has been amply demonstrated during recent times. The Nepean Reservoir was, on the calculations of the Special Board of Reference, due to be commenced as soon as practicable after 1923. Owing to circumstances already described, it was not finished until 1935. In the meantime, a drought closely parallel to that of the record of 1904-1910 set in (commencing in August, 1934), and continued for four years, until in August, 1938, prolific rains fell all over the catchment area, and increased the volume of water stored to 73,317 million gallons. Prior to this, the volume of stored water has been reduced to 37,712 million gallons, i.e., approximately one year's supply at full consumption rates, and steps had had to be taken in



STORAGE POSITION AND RELATIONSHIP WITH 1904-10 DROUGHT.
Figures shown on left indicate storage in million gallons.

March, 1937, to obtain supplementary supplies from the Warragamba River (see page 146) as an emergency matter, and later (during July and August, 1938) to impose restrictions on the use of water. Had the Nepean Dam been finished to schedule, or even so late as August, 1934, it would have been filled by the abundant rains that fell prior to the last mentioned date, and the difficulties and anxieties that prevailed for nearly two years would have been avoided.

Some discussion did, in fact, take place between 1931 and 1933 as to the need or otherwise for resuming construction of the Nepean Dam, due to the fact that during those years the other three dams had remained practically full, and the Board—very wisely, as events turned out—decided to do so, irrespective of the urgent demands of other works such as water and sewerage reticulation.

The experience of 1934-1938 is, therefore, of particular value in emphasising the importance of the principle of having, and adhering to, a standard based on statistics extending over the whole range of recorded knowledge.

Diversion Works and Upper Canal

The original diversion weirs have continued as designed, except that the second one, at Broughton's Pass, has been rebuilt in concrete, following its destruction by flood on 14th February, 1898, when abnormal rainfall caused the Cataract River to rise to the record height of 16-ft. over the crest. It has also had added to it, in 1901, a solid concrete apron on the downstream side to prevent the erosion of faulty rock.

The Nepean tunnel has remained unaltered, although during the drought of 1937 its capacity was temporarily increased to 108 million gallons per day by the raising of the crest level of the Pheasant's Nest weir by 4-ft. (by timber construction).

The upper canal has required extensive re-conditioning. This began in 1896 when, owing to the deterioration of the cement lining and of the lengths lined with shale or stone pitching, it became necessary, in that and the succeeding three years, to improve the watertightness of the canal and to recondition a length of approximately 30,000-ft. This was followed in 1909 by similar work on a further length of 18,500-ft. (during which certain sections between Cataract tunnel and Campbelltown service reservoir, in which a rocky, uneven bottom existed, provided lodgment for silt, etc., were re-graded and the flow improved) and between 1911 and 1918, the whole of the remaining length of the canal was similarly treated.

During 1935-37, the nine wrought iron aqueducts were completely cleaned internally of rust (by sand blast) and lined with cement mortar $1\frac{1}{2}$ inches thick, jetted on by compressed air. In the same period, a paved

road (including bridges across the gullies) was laid alongside the canal to facilitate maintenance. Sixteen reinforced concrete bridges have been built over the canal for road and access purposes.

Prospect Reservoir

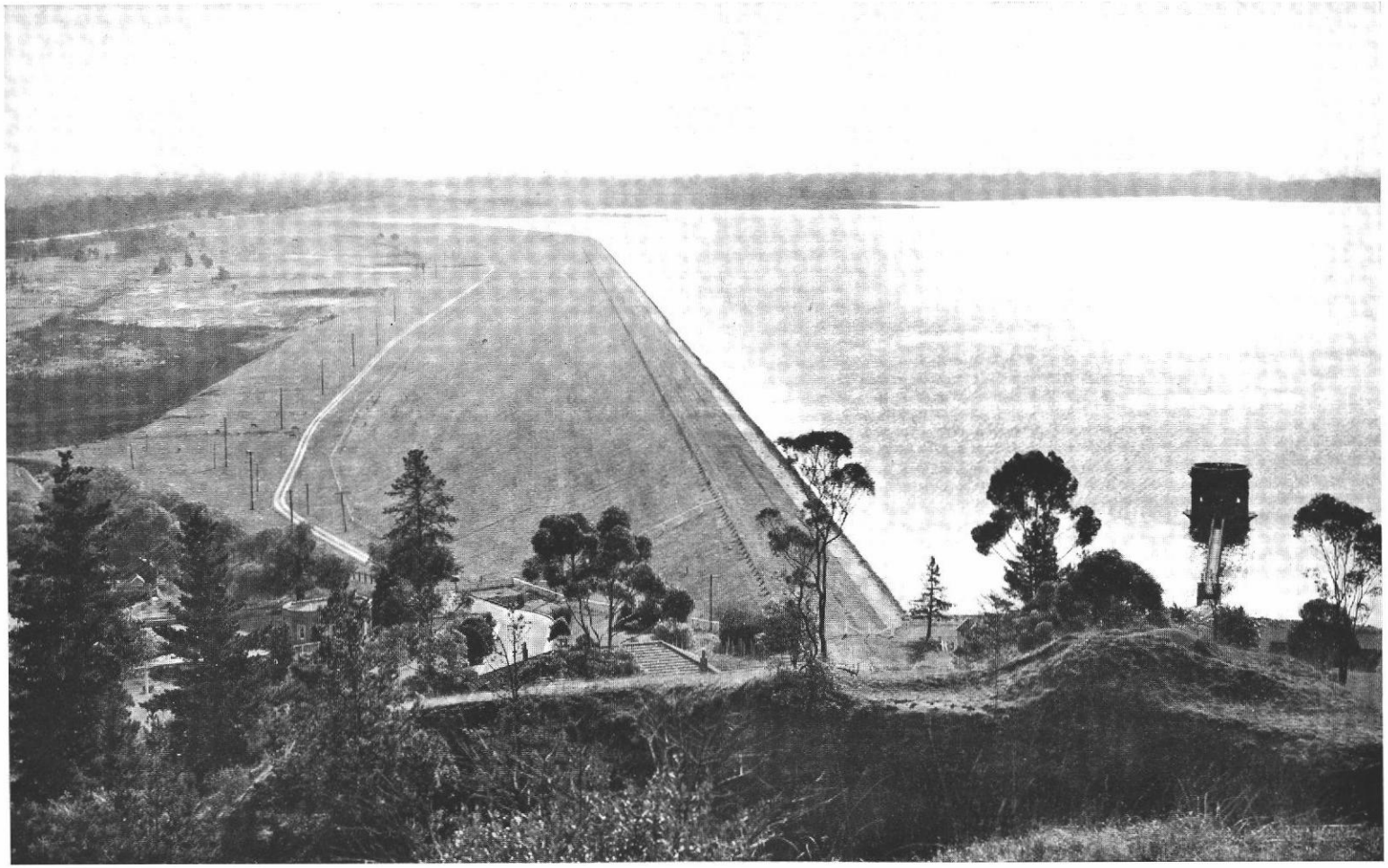
Up to the stage of the completion of Cataract Dam, Prospect Reservoir remained the main storage reservoir of the metropolitan system. Before this eventuated, its capacity for this service had been considerably reduced below that nominally provided (11,029 million gallons), by restriction of levels as a result of certain movements that had taken place in the earth wall. These movements are interesting as illustrating the problems associated with the construction and maintenance of large earthen embankments.

Shortly after the reservoir was transferred to the Board in 1893, movements were noticed on the top of the embankment. Investigation showed that, owing to the retentive nature of some of the clay used in constructing the outer slope of the dam, water soaking in from the surface of the slope was being impounded. Several tunnels were driven in along the base of the embankment, releasing a large quantity of soakage water. The tunnels were then converted into permanent rubble drains and had the effect of checking the movements in the embankment for the time being.

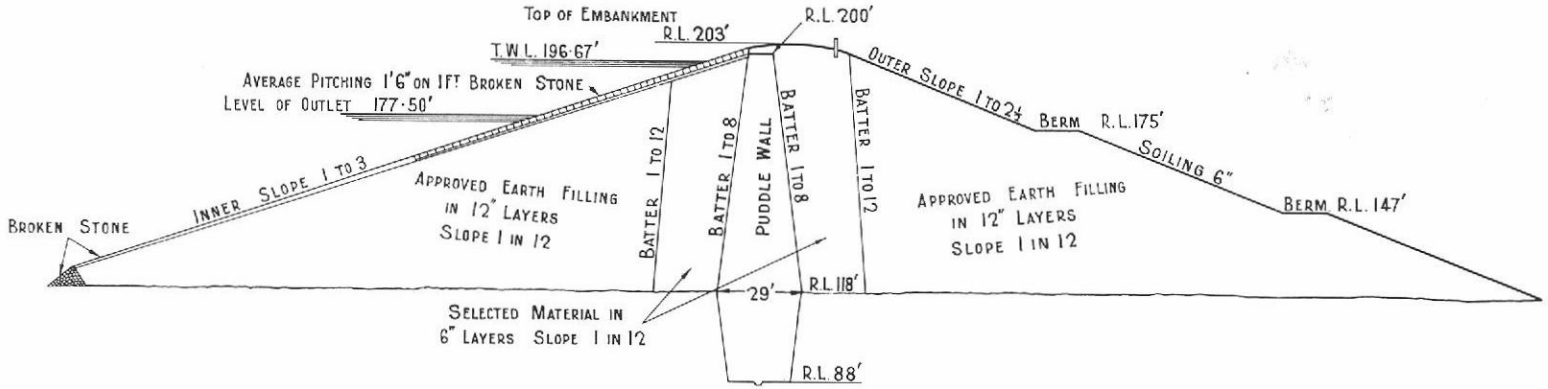
In 1898 the spillway crest level was raised from 195-ft. to 196.67-ft above sea level, increasing the storage capacity to that given above. The puddle wall was similarly raised at that time.

In the early part of 1897, and again in 1899, when the water level fell over 10-ft., subsidence of the embankment again occurred on the inner slope at 4,400-ft. from the north-eastern end of the bank. To remedy this, the toe of the slope, for a length of 600-ft., was weighted by the deposition thereon of 12,000 yards of blue metal spawls from the Board's quarry nearby and the clay puddle core was renewed. A new road was also constructed below the embankment to avoid vehicular traffic thereon.

In 1902, when severe drought caused the level of water in the reservoir to be reduced by about 16-ft., movements in the embankment again took place, once more principally at 4,400-ft. and 6,600-ft. from the north-eastern end. This necessitated extensive re-making of the puddle wall down to a maximum depth of 40-ft. and weighting the toe of the embankment. The Chief Engineer (Mr J. M. Smail, M.Inst.C.E.), in his report of 1902, stated: "The dam has been examined by the Royal Commission (see page 74) and the Works Department's engineers, and the view of the Board's staff is concurred in, that the movements are entirely local, admitting of treatment, and do not involve the stability of the dam as a whole."



PROSPECT RESERVOIR.


TOP OF EMBANKMENT
R.L. 203'
R.L. 200'
T.W.L. 196·67'
AVERAGE PITCHING 1'6" ON 1FT BROKEN STONE
LEVEL OF OUTLET 177·50'
OUTER SLOPE 1 TO 2½
BERM R.L. 175'
SOILING 6"
BERM R.L. 147'
INNER SLOPE 1 TO 3
BROKEN STONE
APPROVED EARTH FILLING IN 12" LAYERS SLOPE 1 IN 12
BATTER 1 TO 12
BATTER 1 TO 8
PUDDLE WALL
BATTER 1 TO 8
BATTER 1 TO 12
APPROVED EARTH FILLING IN 12" LAYERS SLOPE 1 IN 12
29'
R.L. 118'
SELECTED MATERIAL IN 6" LAYERS SLOPE 1 IN 12
R.L. 88'

PROSPECT DAM

TYPICAL CROSS SECTION

CREST LENGTH. 7321 FT – MAX. HEIGHT 85FT – MAX. WIDTH AT BASE 514 FT

The extent of the remedial work then undertaken may be judged from the fact that the expenditure incurred amounted to:—

Re-making puddle wall	£5,650
Weighting toe of embankment	£8,226

Liberal watering of the embankment was found in later years to check effectively any tendency to movement.

With the completion of the large storage dams on the rivers, the function of Prospect has changed largely from that of a storage reservoir to that of the main service reservoir and sedimentation basin of the metropolitan system. Its inflow and outflow can therefore be so regulated that the water level does not fall more than six feet, and thus the stability of the embankment is preserved. The storage available between the limits of rise and fall mentioned is 1,951 million gallons, which is now regarded as the normal holding capacity of Prospect, from a storage point of view.

In 1924, the by-pass, consisting of 1¾ miles of 30-inch cast iron pipes, which connected the upper canal above the measuring weir outside of the dam with the 48-inch pipe discharging into the lower canal from the reservoir, was disconnected from the latter and extended to permit of its free discharge, when in operation, into the lower canal, and certain 48-inch pipes leading from the outlet valve house to the site of the emergency pump house not being required any longer, were removed and used in the construction of the 48-inch pipeline from Pipe Head to Ryde.

In 1937, the section of the 30-inch by-pass between the upper canal and Prospect spillway was taken up, being superseded to that extent by the 72-inch main from upper canal to Pipe Head, Guildford, completed in that year.

Prospect reservoir and its surroundings form an interesting link with the early history of New South Wales, inasmuch as the larger portion of the area of 2,000 acres resumed in connection with its construction, together with the historic residence known as "Veteran Hall," was formerly held by William Lawson. From this homestead, he departed to meet Messrs. Blaxland and Wentworth at the former's farm at South Creek, whence they started on their memorable journey across the Blue Mountains, and there, after he resigned his military appointment, he spent the evening of his life until he died in June, 1850. This house was the residence and local office of the Board's engineer in charge of the head works from 1888 to 1912, after which it was leased until 1915 to the Commonwealth military authorities with the surrounding paddocks as a remount depot. Subsequently it was offered to the Commonwealth Government as a home for returned invalid soldiers, but this being declined, it was demolished in 1929, being then in a dilapidated condition and subject to acts of vandalism.

The approach to the reservoir from the main Western Road is a picturesque one, along a tree-lined avenue with the still waters of the large lake spreading out to the distant wooded uplands. In the early years, the heavy scrub on part of the slopes surrounding the reservoir was thinned out and over 4,000 indigenous trees of various kinds were planted. The grounds immediately adjacent to the reservoir where it discharges into the lower canal are tastefully laid out with garden beds. Employees' cottages in brick with tiled roofs lend an atmosphere of homeliness to the scene. Two quarries adjacent to the reservoir are leased to blue metal crushing companies on a royalty basis.

Lower Canal

The increasing consumption of the Metropolis made it necessary for the Board, in 1902, to initiate the work of raising and lining the lower canal, with a view to strengthening weak sections and increasing its capacity.

The first section dealt with was that known as the "long bank." A difference of opinion between the Public Works Department and the Board arose as to the method of treatment, the former favouring concrete, and the latter monier plates. To test the position, 1,909 lineal feet were re-constructed in concrete, and 646 lineal feet in monier plates. The execution of this work then formed the subject of an enquiry by the Parliamentary Public Works Committee, as a result of which it was recommended that the project should be carried to completion on the lines proposed by the Board. In 1905, Parliament gave the necessary authority for this to be done. By 1907, the work had been completed from Prospect to Boothtown Bridge, a distance of 2½ miles. In that year also, a reinforced concrete inverted syphon 10-ft. 6-ins. in diameter was constructed alongside the existing Boothtown aqueduct. This was the largest continuous concrete work of its kind constructed in Australia up to that time. Its function was to replace the old brick aqueduct (the sides of which had collapsed in 1892 and had been re-constructed) for general use, but the latter was overhauled and retained for service if emergency required it. The raising and lining of the whole length of five miles of the lower canal was completed in 1912.

The work thus took eight years to complete, due largely to difficulties created by the old canal being lined with patchy and inferior concrete and laid out on a hit or miss method of curve connections and defective invert grade lines, together with the necessity of maintaining the supply to the metropolitan area.

The canal, as re-constructed, had its capacity increased from 50 to 93 million gallons per day.

Pipe-head Screening Chambers

Originally the basin at Pipe Head served only to provide a junction between the lower canal and the 72-inch pipeline conveying the water to Potts Hill Reservoir. Since 1913, it has had transferred to it the screening that was previously carried out at Potts Hill Reservoir, and from the offices established about it, all operations involving the head works are now controlled.

The screening chambers are three in number, each 250-ft. long by 40-ft. wide, fitted with sluice gates at entrance. A central channel 12-ft. wide for unscreened water runs the full length of each chamber, and water is drawn through double screens at either side into clear water channels governed by penstocks and leading into a clear water basin 25-ft. wide extending along the ends of the three chambers. This clear water basin is divided into three sections, connected by penstocks and by-passed at the back of the outlet penstocks, so that each section can be emptied for cleaning or repairs without interfering with the supply.

The screens are divided up into a number of bays on either side of the channel in each section, and in the two chambers first constructed, each of these bays can be shut off while the operating screens are being hosed and cleaned. Electric cranes are used for lifting the screens. In the chamber last built, the screens are so fitted that they can be hosed *in situ* and the bays drained of the wash water and cleansed before the chamber is again brought into use.

The fabric of the original screens was composed of fine copper mesh wire (625 to the square inch), but later screens are of phosphor bronze.

The first main screening chamber was constructed in 1913, the second in 1918, and the third in 1928.

72-inch Mains, Pipe Head to Potts Hill Reservoirs

There are now three metal mains, each of 72-inch diameter laid above ground or in cutting, which convey the water from Pipe Head basin to Potts Hill Reservoirs, a distance of about five miles.

No. 1 main was laid as part of the original scheme, and is constructed of wrought iron riveted pipes, connected with steel collars with lead joints. In 1901, it was emptied and cleaned inside, the outside being coated with cement wash. During this process, which proved somewhat lengthy, the exposure of the main to varying temperatures while empty, set up strains which necessitated the re-setting of the lead joints, and collars which failed on recharging the main were repaired by means of straps. Between 1914 and 1923, enveloping collars were put on all the joints to increase their strength and watertightness. In 1922 and 1923, several hundreds of the concrete cradles were renewed in reinforced concrete.

Between 1925 and 1928, the main, which was badly corroded in parts after 40 years' service, was cement lined in sections as it could be laid off duty during the winter months. Improved speed in the execution of the work was obtained by removing one pipe between every two existing manholes, thus providing better access and ventilation. Air compressors were also employed to facilitate scaling and spraying.

No. 2 main, constructed with mild steel pipes with angle iron flanged joints, and coated internally with asphaltum, was completed and put into service in February, 1900. By-passes connecting it with No. 1 main were provided, admitting of alternate use in addition to combined use, with or without passing the water into Potts Hill Reservoir. The original external coating of No. 2 main did not stand exposure, and it was re-coated with a mixture of boiled oil and cement, which proved most successful. In 1909 and 1910, the whole of the flanged joints had to be recaulked to prevent weeping. In 1914, the portion of the main lying in deep cutting at Potts Hill was encased in concrete, and the cutting filled in and levelled off. In 1917 and 1918, it was reported that leaking rivets and seams required the constant attention of a boilermaker.

In the winter of 1928, the main was thoroughly cleaned and cement lined, but owing to improved methods resulting from experience in lining No. 1 main, the work was executed with much greater despatch than formerly. Short lengths of pipe were cut out at numerous points to expedite operations.

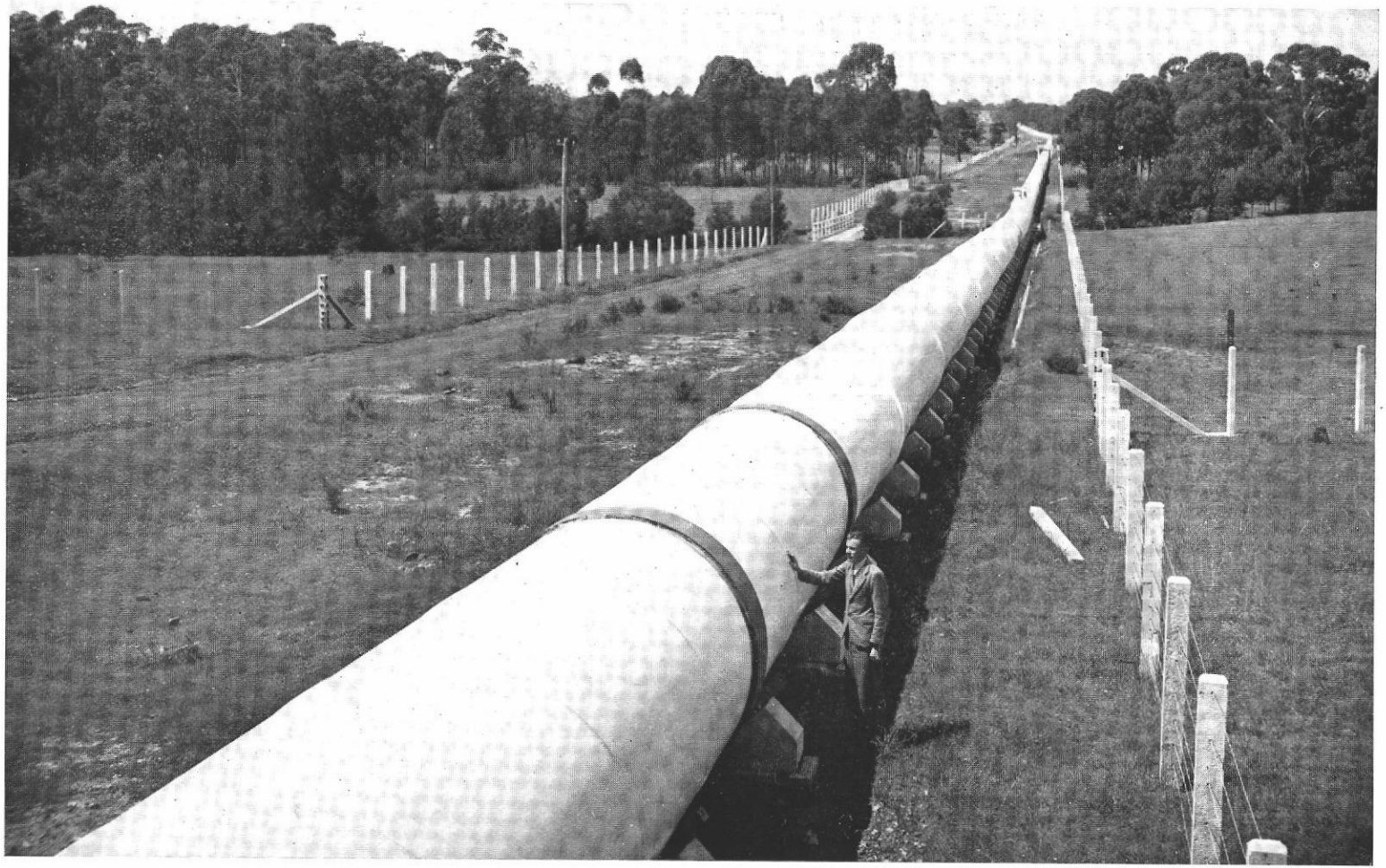
No. 3 main was constructed and put into service in September, 1925. It is made of electrically welded steel pipes in 12-ft. lengths, with collars and full run lead joints.

The first section, about 3,000-ft. in length, is made of plates 7/16" thick, and was internally coated with bitumastic enamel immediately after being laid to prevent corrosion. The second section, about 20,760-ft. in length, is constructed of plates 3/8" thick. The pipes in this section were lined with 1½" of cement concrete applied by spinning, at works erected at Regents Park adjacent to the pipe line.

In 1915, penstocks were fixed on the mains to allow of water being by-passed from the screening chamber to the mains direct when the clear water basins are emptied. The valves also provide for the mains being emptied singly.

Amplification of Supply Between the Upper Canal, Pipe Head, and/or Potts Hill

The lower canal, which conveys the water released from Prospect reservoir for five miles to Pipe Head, is capable of delivering about 93 million gallons per day. In 1926, in view of the fact that the maximum summer draught exceeded the capacity of the lower canal, the provision of a supplementary feed from the upper canal to Pipe Head and Potts



UPPER 72″ MAIN. (UPPER CANAL TO PIPE HEAD). COMPLETED IN 1937.

72″ MAINS. PIPE HEAD—POTTS HILL AND 46″ WOOD STAVE MAIN.

Hill reservoirs became a matter of urgency. The Board therefore approved of the laying of a woodstave main to function in this manner, the selection of woodstave instead of steel being determined by the need to avoid the delay which would have been involved in obtaining pipes manufactured of the latter material. The main could supply 50 million day gallons to Pipe Head and Potts Hill or 33 million day gallons to Potts Hill. The pipes were supplied and laid by the Australian Wood Pipe Co. Ltd., in trench and on track constructed by Board's labour. The main is 54-ins. in diameter from the upper canal to the offtake branch (which is 44-in. dia.) at Pipe Head; from there it is 46-in. in diameter and generally follows the route of the 72-inch mains to the distribution chamber at Potts Hill Reservoir. The pipes are machine banded for the greater length laid in trench, and continuous woodstave between Pipe Head and Potts Hill. The main was completed at the latter end of 1927.

With its completion, the conduits for conveying the water from Pipe Head were increased from one 72-in. pipeline in 1888 to three 72-in. pipelines and one 46-in. pipeline in 1927. Within this period, the average daily consumption of water had increased from 8,144,169 to 74,650,106 gallons. This additional main enabled the water to be kept at a higher level than hitherto in the Potts Hill reservoirs, thus improving output to trunk mains radiating from this centre to supply Sydney and suburbs.

The decision to supplement the supply between the upper canal and Potts Hill by a woodstave main was adopted as a temporary measure to meet the urgency of the position as it had developed in 1926. By 1929 the demand had still further increased, and the Chief Engineer (Mr. G. Haskins) found it necessary to include in his amplification proposals the construction of a 72-in. diameter steel main between the upper canal and Pipe Head, to supplement and later supersede the woodstave line previously laid between these points. Preliminary operations were begun in February, 1931, but owing to the incidence of the financial depression referred to on page 34 the work had to be stopped a few months later. It was resumed in 1933 as part of a special unemployment relief programme arranged with the Government, when after prolonged discussion with the latter as to the type of main (woodstave or steel) which should be adopted, the Board proceeded with its original intention, and a contract was let to Mephan Ferguson Pty. Ltd., in November, 1934, for the supply of 72-inch spirally welded steel pipes in 27-ft. lengths. This was the first pipe of this manufacture used in the Board's works.

The main was completed in the early part of 1937, and its use now enables the lower canal to be laid off in winter for maintenance or repairs. It is laid on the surface on concrete cradles, excepting for a short length in cutting. Screening chambers have been constructed on it adjoining its connection with the upper canal, while a branch enables

water to be drawn off from Prospect Reservoir. It has a capacity of 84 million gallons per day under the head from the upper canal, and 45 million gallons per day under the head from Prospect.

Potts Hill Reservoirs

When the Board took over control, the balance reservoir provided at Potts Hill to tide over any stoppage of supply through the lower canal or the 72-inch pipeline from the end of that canal to Potts Hill, had a holding capacity of about 10 days' supply to the Metropolis. By 1910, the capacity of this reservoir represented less than two days' supply at the average daily summer consumption rate, and after enquiry by the Parliamentary Public Works Committee, an Act (No. 25) was passed on 22nd December, 1910, authorising the construction of a second reservoir with a capacity of 150 million gallons. This was commenced in February, 1913, and completed in July, 1923, a total capacity of 175¾ million gallons being provided.

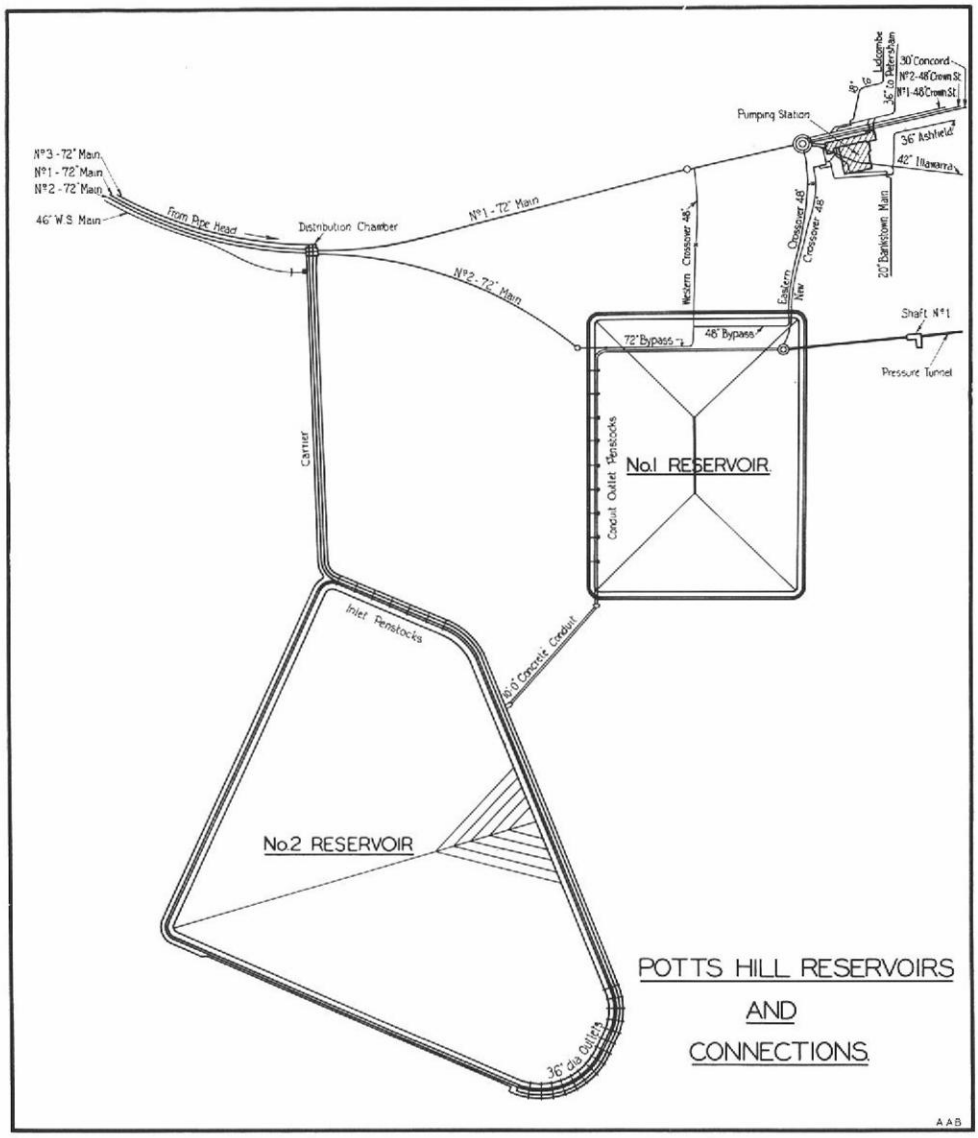
The No. 1 or original reservoir is built partly in bank and partly in excavation, the bottom being of hydraulic lime concrete and the sides of dry coursed rubble masonry. Other particulars in respect of it are:—

Top Water Level	175-ft. above H.W.M.
Length	1,194-ft.
Width	894-ft.
Available Depth of Water ..	15-ft. 6-ins.
Lake Area	24½ acres.
Available Capacity	96,110,000 gallons.

Originally this reservoir was filled by a branch pipe 4-ft. in diameter off the No. 1, 72-inch main, which ran direct to the Potts Hill screening tank. The No. 2, 72-inch main, completed in 1900, discharged direct into the reservoir but was also carried through it and across to connect with the No. 1, 72-inch main. A 48-inch branch also enabled the No. 2 main to feed the screening chamber. This was later duplicated.

Following the transfer of the screen station to Pipe Head, the original screening tank at this reservoir has been used solely as a distribution chamber.

No. 1 reservoir has had a somewhat chequered career. In 1894, a slip took place in a section of the eastern bank through the action of pipeclay in the material forming the bank. The whole of the eastern slope was accordingly strengthened by building a dry rubble wall at the back of the pitching. In 1904, the pitched facing on the north side collapsed, sliding bodily into the reservoir similarly to the eastern slope in 1894. The remedial measures applied were the same as in the former instance. In 1909, the western outlet crossover from the reservoir burst. It was built in brick and concrete, no doubt owing to shortage of cast


N°3 - 72" Main
N°1 - 72" Main
N°2 - 72" Main
46" W.S. Main
From Pipe Head
Distribution Chamber
N°1 - 72" Main
N°2 - 72" Main
Carrier
Pumping Station
Western Crossover 48"
Eastern Crossover 48"
New Crossover 48"
20" Bankstown Main
36" to Lidcombe
8" to Meter Stn
30" Concord
N°2-48" Crown St.
N°1-48" Crown St.
36" Ashfield
42" Illawarra
Shaft N°1
Pressure Tunnel
72" Bypass
48" Bypass
No.1 RESERVOIR
Conduit Outlet Penstocks
Inlet Penstocks
9'-0" Concrete Conduit
No.2 RESERVOIR
36" dia Outlets
POTTS HILL RESERVOIRS
AND
CONNECTIONS
AAB

iron pipes during construction of the reservoir. It was reconstructed with cast iron pipes. In 1914 and 1915, small slips occurred on the eastern bank due to the water level topping the puddle wall which had subsided. The bank was rebuilt where affected.

In 1919, a further slip occurred on the eastern bank. It was repaired temporarily by removing the pitching and substituting bags of pug up to top water level and sodding the remainder. This slip was permanently repaired in 1926, when the reservoir was emptied for cleaning following the completion of the No. 2 reservoir. The slip was cut out and refilled with spawls set in concrete, the face being set up with pitchers and concrete blocks.

No. 2 reservoir consists of gravity concrete walls and concrete floor. A concrete carrier conveys the water from the 72-inch mains to fill the reservoir, a concrete conduit connecting it with No. 1 reservoir. Other particulars in respect of it are:—

Top Water Level	178.5-ft. above H.W.M.
Max. Length	1,820-ft.
Max. Width	1,600-ft.
Available Depth of Water ..	12.5-ft.
Lake Area	52 acres.
Available Capacity	175,750,000 gallons.

Summary of Development of the Head Works of Sydney Water Supply: 1888-1938

The main developmental works in the section from the catchment area to Potts Hill, which may be taken to mark the termination of the Head Works, may be summarised as follows:—

(i) Four large storage dams constructed on the Cataract, Avon and Upper Nepean Rivers, respectively, with aggregate storage capacity of 106,391 million gallons and costing in the aggregate nearly £4,000,000. Completed in 1907, 1926, 1927 and 1935 respectively.

(ii) Supplementation of the Lower Canal by:—
  (a) Raising and lining, increasing its capacity by 75 per cent. Carried out between 1902 and 1912.
  (b) Laying a temporary 54-inch woodstave main from Upper Canal to Pipe Head—completed in 1927, and a permanent 72-inch steel main with screening chambers from Upper Canal to Pipe Head—completed in 1937.

(iii) Installation of large screening basins at Pipe Head to supersede the original screening tank at Potts Hill Reservoir which had become inadequate. Constructed in three sections between 1913 and 1928.

(iv) Trunk pipe line between Pipe Head and Potts Hill Reservoirs increased from one 72-inch metal main in 1888, to three 72-inch metal mains and one 46-inch woodstave main. The two additional steel mains were laid in 1900 and 1925 respectively, and the woodstave main in 1927.

(v) Potts Hill Reservoirs: Construction of No. 2 Reservoir with capacity 50 per cent greater than No. 1 Reservoir. Completed in 1923.

These works represent a capital expenditure of £5,700,000.

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CHAPTER X

UPPER NEPEAN SCHEME—DEVELOPMENT SINCE 1888

SOUTHERN DISTRIBUTION SYSTEM—(METROPOLITAN)

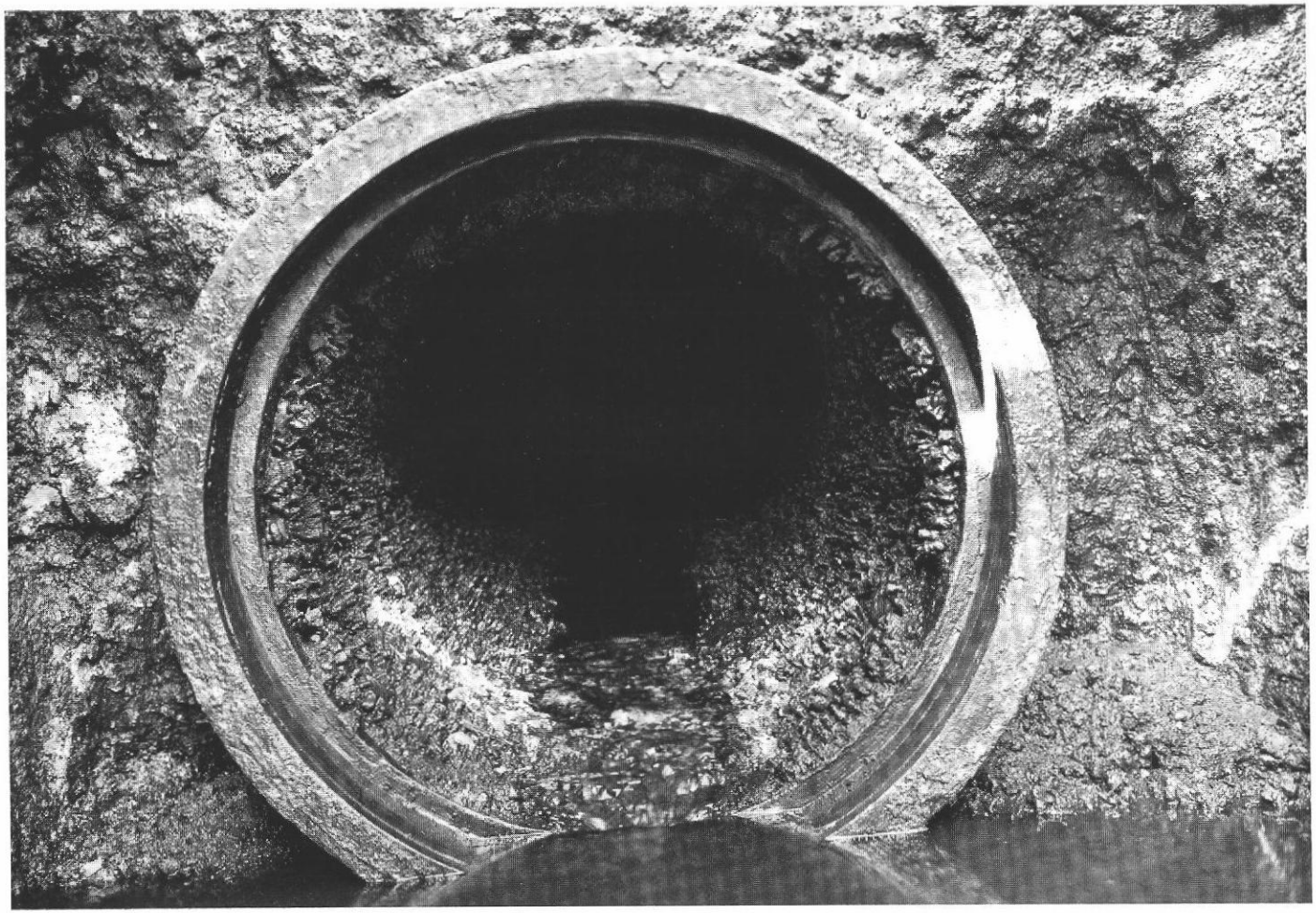
Trunk Mains, Potts Hill Boosting Station and Pressure Tunnel.

Water supply distribution to Sydney and suburbs on the south side of Parramatta River and Sydney Harbour commences at the Potts Hill Reservoirs. In 1888, when the Board assumed control, the water was conveyed from Potts Hill through a single line of 48-inch cast iron pipes diminishing to 42-inch diameter at the point where a 48-inch branch connected with a reservoir built at Petersham and continuing on to Crown Street Reservoir. From here water was pumped to reservoirs at Paddington and Woollahra and from Woollahra water was pumped to a reservoir at Waverley. From these reservoirs the water was distributed through about 400 miles of arterial and reticulation mains to the City and 23 suburban districts.

Almost immediately a second main pipeline from Potts Hill to Crown Street became necessary. This was constructed by the Harbours and Rivers Department (then the constructing department for water supply works) and transferred to the Board in 1893.

For several years the water was delivered from these two trunk mains to two centres only, viz., Petersham Reservoir from the original 48-inch main, and Crown Street Reservoir from the original and the No. 2, 48-inch main. From Petersham Reservoir the water was distributed to such of the Western and Illawarra suburbs as were supplied at that time. A pumping station at Carlton lifted water delivered from Petersham Reservoir to tanks at Penshurst for supply to the higher levels of Kogarah. From Crown Street Reservoir, the City and near suburbs within gravitation limits were supplied, the reservoirs at Paddington, Woollahra and Waverley serving localities above Crown Street gravitation. Water from Woollahra was also fed back to a tank on the heights of Ashfield for supply to the higher levels of that district.

As the Western Suburbs extended and developed, it became necessary to provide numerous branches off the No. 1, 48-inch main to supply gravitation areas *en route*. The No. 2, 48-inch main was, and continued to be, reserved for supplying suction water to the central Crown Street



INTERIOR OF 48″ CAST IRON MAIN (NOT CEMENT LINED) BEFORE CLEANING AFTER 42 YEARS USE.

pumping station and in later years, following the establishment of the Waterloo pumping station, to that one also.

The two 48-inch mains comprised the sole feeders from the Head Works to the Southern Distributory system for some fifteen years, until by 1905, the following additional trunk feeders were provided to relieve the draw on them:—

30-24-20-inch (formerly used for the Northern system to Ryde) from Potts Hill to the Western Suburbs and Drummoyne.

15-inch off 72-inch main above Potts Hill at Woodville Road to supply Granville.

18-inch from Potts Hill to supply Rookwood, Auburn and Granville.

Despite this assistance, by 1911, the two 48-inch mains were barely able to cope with the peak summer consumption and in the light of the ever increasing demand, major as well as minor means of supplementing or increasing their capacity had to be sought.

The first of these, and the one that had to be progressively developed until the major solution of the problem (the pressure tunnel described later) was available, was the installation of a boosting plant at Potts Hill, to increase the delivery capacity of the mains by improved head. The degree to which this had to be done is illustrated by the following statement showing the quantity of water so boosted:—

Year ending	Million Gallons	% of total supply of Southern System
30th June, 1913	3,934	42
" 1918	4,623	38
" 1923	9,783	62
" 1929	18,000	71
" 1935	19,542	70

The first plant installed for the purpose (in 1912) consisted of two 16-inch Gwynne Centrifugal pumps direct coupled to two Wolff crank compound vertical jet condensing engines with two Babcock and Wilcox boilers, and a 26-inch Worthington centrifugal pump direct coupled to a vertical compound jet condensing Browett-Lindley engine with two Babcock and Wilcox boilers. The two first-mentioned pumps were connected to the No. 2 main and the last to the No. 1 main. Subsequently, the following additions were made:—

1916 A second 26-inch Worthington centrifugal pump with Browett-Lindley engine.

1918 A third unit of 26-inch Worthington pump and Browett-Lindley engine in replacement of the Gwynne pumps and their associated engines, the pumps of which were transferred for pumping to Bankstown Reservoir.

1923 A 24-inch centrifugal pump of Board's design coupled to an Allen engine transferred from Ryde pumping station, and two additional B. and W. boilers. This set took over the duty of boosting the 36-inch Leichhardt main constructed in 1921 (see later).

1924-5 Two 18-inch two stage Briton volute centrifugal pumps, each coupled to a Belliss and Morcom vertical compound engine, for pumping to Bankstown in replacement of Gwynne pumps which had become unreliable.

1927 Two Worthington-Simpson 22-inch two stage centrifugal pumps each direct connected to a Belliss and Morcom compound engine (to boost water through the 42-inch-36-inch Illawarra trunk main) and two Briton double-suction single stage 22-inch centrifugal pumps, each direct connected to a vertical 3-crank triple expansion Browett-Lindley engine (to boost water through the 36-inch Wattle Hill-Concord trunk main constructed in 1927—see later).

The second means of assisting the two 48-inch mains was by the construction of additional trunk mains to provide independently for areas intermediate between Potts Hill and Crown Street. During 1915-27, the following mains were so laid:—

1915 42-36-30-inch cast iron main from Potts Hill via Roberts Road, Canterbury to Cooks River Valley to supply Bankstown, Canterbury and Illawarra Suburbs formerly supplied from Petersham Reservoir.

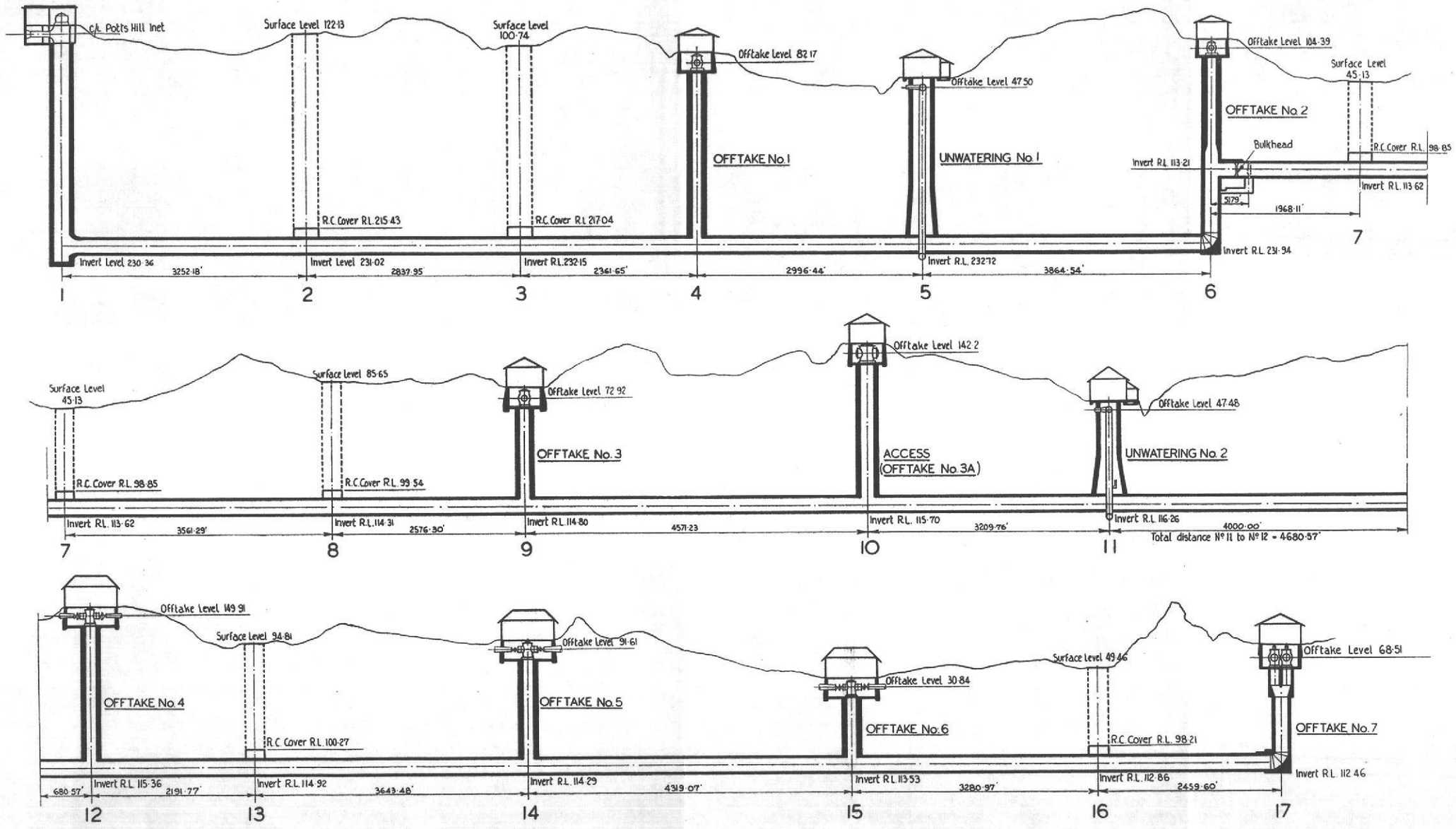
1921 36-inch cast iron main from Potts Hill through Western Suburbs to Leichhardt, enabling, by connection to 30-inch main from Centennial Park Reservoir at Petersham, the areas supplied from that reservoir to be contracted.

1921 20-inch cast iron rising main from Potts Hill to Bankstown Reservoir.

1927 36-30-24-inch cement lined cast iron main from Potts Hill to Wattle Hill, Ashfield, Concord and Drummoyne.

The third and the major means of relieving the situation, and providing adequately for the future, was obtained by the construction of a large pressure tunnel between Potts Hill and Waterloo pumping station (see later).

Investigation commenced in 1914 of the various alternatives that appeared available, the delivery capacity sought being 100 million gallons per day. This would have required no less than eleven 48-inch mains, if laid near the surface and without boosting, and the interference with roads, buildings, subways, sewers, street mains, etc., would have been enormous—too great, indeed, to be contemplated. The alternative was a pressure tunnel, deep beneath the surface, and this was finally recommended to and approved by the Board in 1915.



PRESSURE TUNNEL

POTTS HILL — WATERLOO

LONGITUDINAL SECTION

A.A.B.

The proposal adopted was for the construction of a conduit from a shaft adjacent to Potts Hill Reservoir to Waterloo pumping station, a distance of 10 miles. To allow of inspection and cleaning, the tunnel was designed as two cylindrical tubes in one heading, each tube being 7-feet in diameter. In 1919, the project was referred to the Special Board of Experts which had been constituted by the Minister of Public Works to review all schemes for the augmentation of Sydney's water supply. After examining its general features and receiving certain assurances regarding the strength of the tunnel in relation to the high internal pressure to be borne and the quality of the concrete to be used in the lining, the Special Board recommended the proposal to the Minister on 11th July, 1919. The estimated cost at that time was £1,000,000. Subsequently, the expediency of carrying out the project was the subject of an enquiry by the Parliamentary Standing Committee on Public Works, which authority, in a report dated 9th August, 1921, endorsed it with a revised estimated cost of £1,408,000. Trial bores were put down during 1921 and 1922, and on 8th March, 1923, the Chief Engineer of the Board (Mr J. G. S. Purvis, M.Inst.C.E.), recommended that a single tube 10 feet in diameter should be substituted for the two 7-ft. tubes and that the tunnel should be constructed throughout at such a depth that it would be embedded in the underlying sandstone rocks. This amended proposal embraced the ultimate extension of the tunnel to Cecil Hills, on the Upper Canal beyond Liverpool, which by reason of the added head would give it a delivery capacity of 145 million gallons per day. This recommendation was approved by the Board and preliminary work began forthwith. Operations commenced by the sinking of 17 shafts. The work was divided into three sections, each with an engineer in charge, section 1 embracing shafts 1 to 6, section 2—shafts 7 to 11, and section 3—shafts 12 to 17. (Numbers commence from Potts Hill.) The finished depth of the shafts varied from 150-feet (shaft No. 15) to 378-feet (shaft No. 1). By June, 1925, the shafts were completed and the driving of the tunnel by two headings at each shaft (excepting at Nos. 1, 6 and 17) had been commenced. To carry out the tunnelling, the Board purchased in August, 1924, two Arrol-Whittaker tunnelling machines, similar to those that had been used successfully for similar work at Bournemouth and Manchester, England. The machines were delivered in June, 1925, and were installed at Shafts 9 and 11. Unfortunately, they proved entirely unsuitable for the task, owing to the nature of the sandstone and its effect on the cutting tools, and ultimately it was necessary to withdraw them and resume driving by manual labour. The first drive completed was from Shaft No. 12 East to No. 13 West in August, 1925. Other sections then followed in rapid succession, until by February, 1927, the driving of the tunnel was completed.

The placing of the tunnel lining, which consisted of sandstone con-

crete of a thickness of about 18 inches, was done by a Webb Concrete Gun, which was installed and operated for some months under the supervision of the patentee, Mr W. F. Webb, President of the Universal Concrete Gun Co. of U.S.A. The concrete was brought to the gun in trains of four one-cubic yard trucks hauled by storage battery electric locomotives. The tunnel lining was completed in 1928, as also was the tunnel connection between the outlet tower of Potts Hill Reservoir and the inlet shaft of the pressure tunnel.

With the object of investigating the safety of the tunnel before placing it in service, the necessary preparations were made in July, 1929, for its testing in six sections. Six heavy steel bulkheads, carried on specially constructed reinforced concrete rings were required for the purpose. Connections of the various sections with the water supply were made by 8-inch pipes equipped with valves, pressure gauges, and meters to enable ready control of inflow and accurate measurement of all water losses. The first test was made from Potts Hill No. 1 shaft to No. 5 shaft, a distance of 2½ miles of the deeper section of the tunnel. The results were satisfactory up to a head of 400 feet. When the full feet head was applied, however, an extensive rupture of the lining occurred over a length of 700 feet where dikes and rock of poor quality had been met. Although it was known that an appreciable quantity of water was getting away, in view of the urgency of amplifying the supply to Sydney, it was decided to place this section of the tunnel in commission immediately. It was utilised throughout the summer of 1929-30 to supply Lakemba pumping station, a 48-inch main being laid from No. 4 shaft to the 36-inch main supplying that station, thus relieving the 42-inch Potts Hill-Illawarra Suburbs main.

Further fractures having developed during the testing of the tunnel between shafts 6 to 9, it was decided that remedial measures were necessary. A number of proposals to this end were placed before the Board by Mr G. Haskins, M.Inst.C.E. (who had assumed charge as Chief Engineer since the death of Mr Purvis in October, 1927), and after the President (Mr T. B. Cooper) and the Chief Engineer had conferred with the Engineer for Water Supply of the Melbourne and Metropolitan Board of Works (Mr E. G. Ritchie, M.Inst.C.E.) and the N.S.W. Commissioner for Irrigation (Mr H. H. Dare, M.E., M.Inst.C.E.) regarding these, the Board approved in June, 1930, of the recommendation to line the tunnel throughout its full length with steel tubes having an inside diameter of 8 feet 3 inches, provided with an interior socket to permit of jointing from inside the lining, the annular space between the tube and the tunnel to be filled with bluestone concrete. The tubes were manufactured in 9-ft. lengths, those for the deeper section of the tunnel being made of plates ½-inch thick and for the other section ⅝-inch thick.

On 9th February, 1931, a start was made with the steel lining of the tunnel. Meanwhile a spun bituminous lining was evolved after an exhaustive series of experiments with various mixtures and plant, and this was substituted for the original proposal to put a 1½-inch cement lining inside the tubes. This change resulted in a saving in cost and gain in the finished diameter of the tube. On 27th March, 1931, work had to be suspended owing to further loan funds not being available.

Operations were recommenced from shafts 1 to 6 in August, 1932, as an Unemployment Relief Work, with funds provided by the Government. At the latter end of 1933 the Board, being again able to raise loan money, the lining of the first section of the tunnel from shafts 1 to 6 was completed, and work on the other section (shafts 6 to 17) recommenced.

The Board then appointed a Committee to supervise the testing of the tunnel, consisting of the President (Mr T. B. Cooper), the Chief Engineer for Water Supply (Mr S. T. Farnsworth, B.Sc. (Eng.) Lond., Assoc. M.Inst.C.E.) and the following:—

Mr H. H. Dare, M.E., M.Inst.C.E. (Commissioner for Water Conservation and Irrigation, New South Wales).

Professor W. A. Miller, M.E., B.Sc. (Glasgow), Professor of Civil Engineering, Sydney University.

Mr G. Haskins, M.Inst.C.E., then in private practice, having retired from the position of Chief Engineer of the Board earlier in the year.

Mr A. J. Debenham, B.E., M.Inst.C.E. (Engineer-in-Chief, Sydney Harbour Trust), representing the Government.

Following extensive tests carried out from January to May, 1934, the Committee reported that the results were highly satisfactory and that it believed the measured leakage to be far less than that ever recorded in respect of a pressure water conduit of such magnitude. In this connection, it is interesting to record that the Potts Hill-Sydney pressure tunnel is the third largest in the world, and that in the cases of the Ritom tunnel in Switzerland and the Moodna Hudson (New York) tunnel rupture took place at the trial filling.

The lining of the second section of the tunnel (shafts 7 to 17 inclusive) Ashfield to Waterloo with the steel tubing was completed in September, 1935, and after tests which gave highly satisfactory results, under the supervision of the Special Testing Committee previously referred to (Mr T. H. Upton having taken the place of Mr T. B. Cooper as President of the Board), the whole tunnel was placed in commission in November, 1935. During the month of May, 1936, the tunnel was emptied and subjected to close inspection by the Testing Committee, its condition throughout the whole length of 10 miles being found to be highly satisfactory. Under present working conditions, its delivery capacity is 100 million day gallons, as the supply can be taken at

Waterloo at a lower pressure than was originally allowed. The cost of the original work was £2,251,111, and of the remedial measures £852,239—total £3,103,350, including offtakes.

In a paper on the construction of the pressure tunnel, contributed by Mr G. Haskins and published in the proceedings of the Institution of Civil Engineers, London (Vol. 234, 1931-32, Part 2), the author stated his opinion that experience in the construction of this tunnel has proved:—

(1) That contrary to the reasonable belief of capable engineers, the Sydney sandstone is not, in itself, a suitable medium for the conveyance in underground tunnels of high pressure water. Such tunnels, therefore, must be provided with an impervious lining.

(2) That an unreinforced sandstone concrete has little, if any, value as an impervious lining against the considerable hydrostatic pressure for which the Sydney pressure tunnel was designed to operate.

(3) That the leakage through an unreinforced concrete lining owing to the porosity and physical characteristics of the sandstone rock, results in the development of high pressure pockets in the rock strata surrounding the tunnel with consequent risk of rupture and leakage of water from the tunnel to the surface.

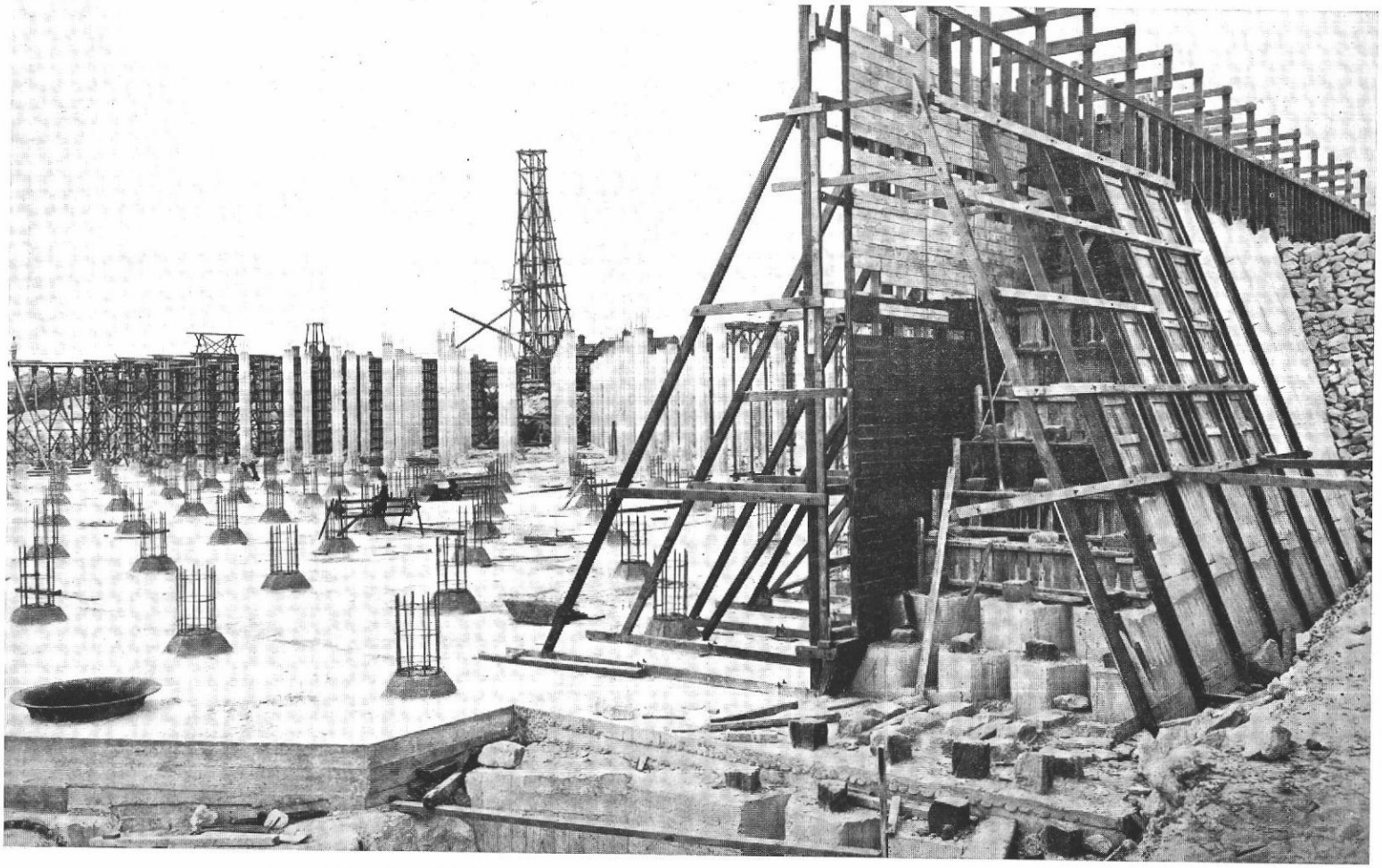
(4) That it is essential that any important conduit of this nature, if constructed in sandstone strata, be provided with an impervious lining which in itself possesses sufficient strength and elasticity to withstand, without fracture and leakage, the full hydrostatic pressure to which it may be subjected.

The pressure in the Sydney tunnel, lower section (Shafts 1 to 6) is about 190 lbs. per sq. inch, which is almost equal to that of the New Croton tunnel and slightly greater than that in the Moodna Hudson tunnel, both connected with New York water supply. In the case of each of these tunnels the minimum depth of cover in sound rock is 150 feet. There is a step up of about 100-feet at Shaft 6 in the Sydney pressure tunnel, and in the upper section the pressure is about 145 lbs. per sq. inch.

The failure of the Sydney pressure tunnel under test was investigated by a Royal Commission which sat from November, 1932, until May, 1933, and reviewed several matters connected with the Board's activities. This Commission, while attributing the failure of the tunnel under test to incorrect design and location, agreed that the remedial measures would be satisfactory from the point of view of safety.

The bringing into operation of the pressure tunnel involved extensive adjustments in the distribution of water in the southern system

VAUCLUSE ELEVATED RESERVOIR.



CENTENNIAL PARK NO. 2 RESERVOIR UNDER CONSTRUCTION IN 1924.

by the substitution of supply ex the tunnel offtakes for boosted water throughout the 48-inch trunk mains. The offtakes which were accordingly laid (during 1935 and 1936) are:—

No. 1. 36-inch diameter main—supplies, from No. 12 shaft, the existing 30-inch Illawarra main and trunk branches serving areas to south-east of Petersham Reservoir previously supplied with boosted water.

No. 2. 36-inch main—supplies Petersham Reservoir from No. 12 shaft. This reservoir was formerly supplied from one of the old 48-inch trunk mains to Sydney.

No. 3. 48-inch and 36-inch mains—supplies water from No. 14 shaft to the lower areas east of Catherine Street, Leichhardt, previously supplied by the 36-inch boosted main Potts Hill to Leichhardt and also to Crown Street pumping station by connection to the 42-inch main Potts Hill to Crown Street.

No. 4. 36-inch main. To reinforce the supply in Erskineville and Alexandria areas previously supplied with boosted water from Nos. 1 and 2 48-inch mains.

No. 5. 60-inch main—supplies water from shaft No. 17 to the No. 2 48-inch main which feeds Crown Street Pumping Station in conjunction with supply from shaft No. 14 and the No. 1 48-42-inch main from Potts Hill.

An 18-inch-15-inch main has been laid from the Centennial Park Reservoir outlet main in the University Grounds as part of the re-arrangement of supply to certain streets in Newtown which were formerly subject to slackness of pressure. This constitutes a benefit arising indirectly from the putting into commission of the pressure tunnel.

The elimination of the need to boost water through the 48-inch mains from Potts Hill has resulted in an economy in pumping costs, estimated at £6,000 per annum, the coal consumed and water pumped at the two stations affected, viz., Potts Hill and Crown Street, being reduced by 27 per cent and 31 per cent respectively.

The function of the two old 48-inch mains is therefore now to deliver water by gravitation, in conjunction with the pressure tunnel, to the lower levels and to Crown Street and Waterloo pumping stations. Potts Hill pumping station still continues pumping and boosting the water for the higher levels of the Western Suburbs.

Pumping Stations.

Three principal pumping stations (other than Potts Hill) are now required to ensure adequate distribution in the southern system and are situated at Crown Street, Waterloo and Lakemba. A fourth also exists at Carlton, but is virtually obsolete. Crown Street pumping station has been an important unit in the water supply of Sydney and suburbs since 1858 when the original plant was installed there by the City Coun-

cil in connection with the Botany Swamps Water Supply to pump water to Paddington Reservoir. In 1881 further plant was added to pump to Woollahra Reservoir. This was the position when the Board took over control in 1888.

Its attention was immediately drawn by its Engineer (Mr J. Trevor Jones) to the precarious condition of the pumping plant and, after prompt investigation, two duplex compound high-duty Worthington engines and pumps with a battery of four 142 h.p. Babcock and Wilcox boilers were ordered from England and installed. (These pumps are still in use.) The new plant took up the duty of pumping to Paddington and Woollahra Reservoirs in March, 1890, the old plant being scrapped. In 1893, an additional pump, designed and erected by Morts Dock and Engineering Co., Ltd., was installed, mainly to pump to Waverley Reservoir. This plant consisted of a pair of engines of horizontal compound condensing rotative direct acting type, placed side by side, each working a double action pump. The whole installation was considerably greater in capacity than the size of the existing reservoirs warranted, but was provided in readiness for the proposed large high level reservoirs at Centennial Park, Waverley and Bellevue Hill.

On the completion of the Centennial Park Reservoir in 1898 and the laying of a 36-inch rising main thereto from Crown Street (141-ft. above sea level), the pumps at Crown Street took up the duty of pumping to Centennial Park, in addition to Woollahra and Waverley Reservoirs, respectively 245-feet, 282-feet and 360-feet above sea level. Paddington Reservoir was put out of commission, being superseded by the larger and higher Centennial Park Reservoir. The rising mains laid by the City Council prior to 1888 from Crown Street to Woollahra (24¾-inches) and thence to Waverley (18-inches) continued in use.

In 1906, the pumping plant at Crown Street was increased by the addition of two 16-inch high-lift centrifugal pumps in series, coupled to a Dick-Kerr motor of 700 B.H.P., connected to the City Council's electricity system.

All the pumps, except No. 1 Worthington, were connected to both pumping mains (36-inches and 24¾-inches) and could thus be used to pump to any of the Eastern Suburbs reservoirs. The water for Randwick Reservoir (erected 1911) was lifted to Woollahra whence it gravitated to the former; the water for Vaucluse was lifted to Waverley Reservoir and gravitated thence to Vaucluse Reservoir; the water for Waverley and Bellevue Hill (erected 1913) Elevated Reservoirs was lifted to Waverley and a small electrically driven pumping plant at Waverley Reservoir raised the water to the two beforementioned elevated reservoirs. In 1913 the rising main between Woollahra and Waverley Reservoirs was increased from 18-inches to 24-inches, enabling the rate of pumpage to Waverley to be increased 50 per cent.

As additional pumping capacity became necessary, the Morts Dock engine and pump, and the two 16-inch centrifugal pumps were replaced, in turn, in 1915, 1918 and 1923 respectively, by other centrifugal pumps, the first supplied by the Parsons Engineering Company, driven by Rees Roturbo Parsons Surface Condensing Turbines (this was the first example of the geared turbine introduced into Australia for use on land), the second, a 15-inch two stage pump manufactured by Thompson & Co., Castlemaine, Victoria, and the third by Kelly and Lewis, Melbourne. In 1922, the original battery of four Babcock and Wilcox boilers was replaced by new boilers with mechanical chain grate stokers, and in 1925, a 750 h.p. motor was installed to take over the driving of the 15-inch Thompson pump supplying Waverley Reservoir.

By 1922, the Crown Street station had reached the limit of its capacity. In that year, a commencement was made with the erection of a large pumping station, to be operated electrically, on part of a 4-acre block at the corner of Young, McEvoy and Bourke Streets, Waterloo, which had been acquired in 1910. In 1923, this new station took over the duty of pumping to Randwick Reservoir, Crown Street being also further relieved of a certain amount of pumping to Centennial Park Reservoir by the boosting of water from Potts Hill through the 36-inch Potts Hill-Leichhardt main which had been connected to the 30-inch main from Centennial Park Reservoir at Petersham. In 1927, relief was again afforded by the transfer to Waterloo pumping station of the pumping to Waverley Reservoir. Since that date, Crown Street has been confined to supplying the Woollahra and Centennial Park Reservoirs.

In 1931, the practice was introduced of confining the winter pumping to steam driven units, the saving by the elimination of pumping by electrically driven units being estimated at £3,200 per annum. Two feed pumps ex Ryde (old) pumping station and two feed heaters (ex Manly pumping station) and two new exhaust heaters complete with duplicate feed line were installed to meet this increased use of steam units.

The volume and growth of pumpage from Crown Street pumping station over 50 years is illustrated by the following figures:—

		Gallons (million)
1889	Pumped to Paddington and Woollahra Reservoirs	1182
1899	Pumped to Woollahra, Waverley and Centennial Park Reservoirs	2887
1909	" " " "	3614
1919	" " " "	5983
1929	" " " "	6135
1938	" " " "	8200

The reasons giving rise to the establishment of the Waterloo pumping station have already been explained. By 1923 the installation of the units in this station for pumping, together with suction and rising mains to Randwick Reservoir had been completed, and this duty was then, as previously stated, taken over from the Crown Street Station. The pumping plant consisted of two sets of Australian General Electric synchronous induction motors of 450 B.H.P., direct coupled to a 12-inch centrifugal pump, complete with automatic press button starter. The suction main (24-inches in diameter) was laid from the No. 2, 48-inch Potts Hill to Crown Street trunk main in Wellington Street, Waterloo, and the rising main (also 24-inch in diameter) direct from the pumping station to Randwick Reservoir. A second suction main of 20-inch diameter was laid from the Potts Hill-Tempe trunk main to Waterloo in 1924 to provide additional suction water for the pumps.

In 1927 an extension of the building to house two 12-inch two stage centrifugal pumps (Morts Dock) with Crompton 500 B.H.P. auto synchonous motors, etc., for pumping to Waverley Reservoir, was completed and the units installed and put into operation. Simultaneously a 30-inch cement lined rising main from the station to Waverley Reservoir crossing Centennial Park was laid.

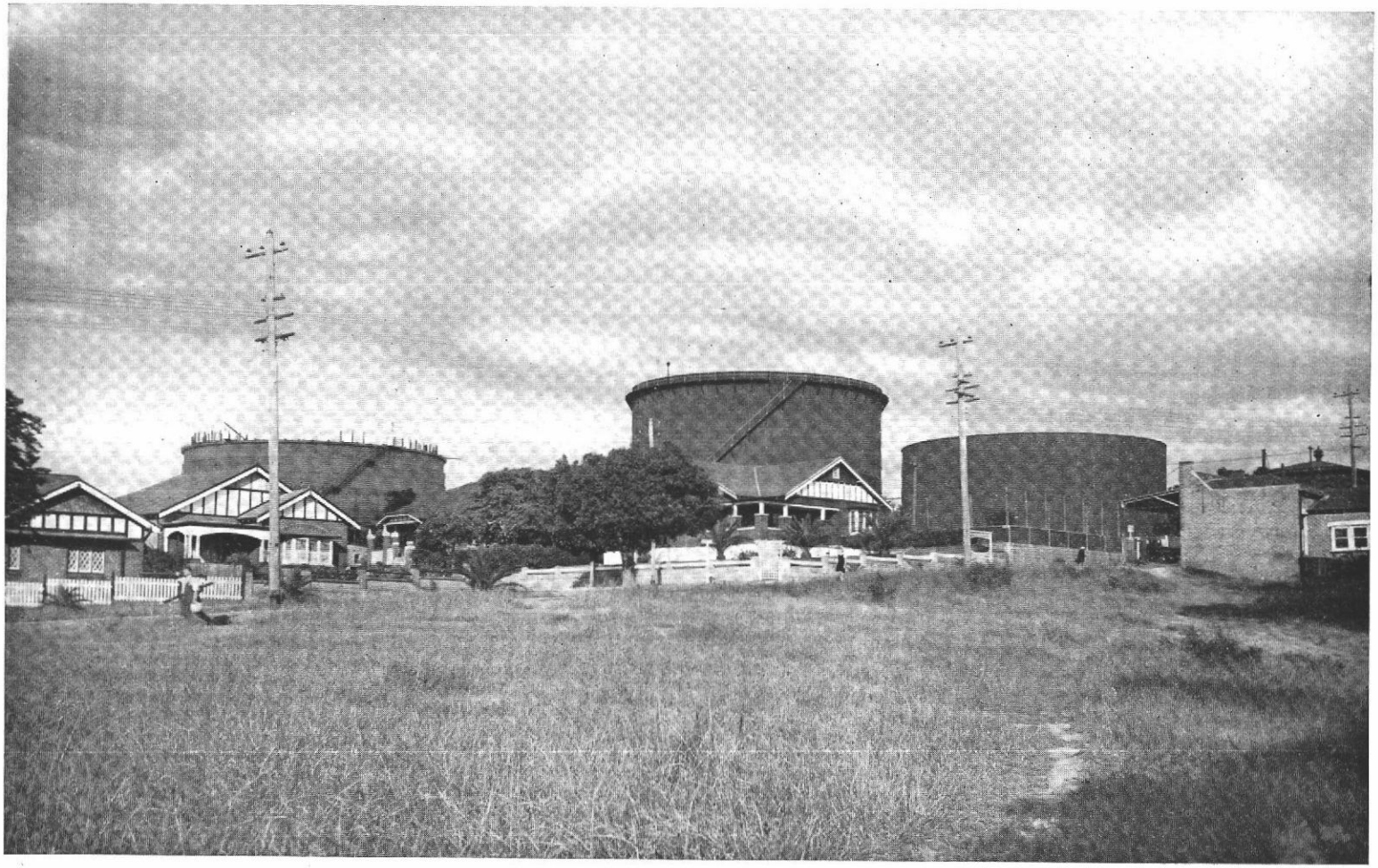
In 1931, the first section of a 48-inch steel cement lined rising main from Waterloo to Waverley Reservoir was completed as far as Moore Park, and linked up with the remainder of the 30-inch rising main to Waverley Reservoir. To provide additional suction water to the pumps, a short 24-inch connection was made from the 33½-inch Botany main to the two suction mains leading into the station.

Since November, 1935, the pressure tunnel has been supplying the suction water to this pumping station.

In 1937, a second section of the 48-inch steel cement lined rising main from the pumping station to Waverley Reservoir, to amplify the supply of pumped water to that reservoir, was completed.

The following is a statement of the annual pumpage from Waterloo pumping station for each second year since the commencement of its operation:—

Year ending 30th June		Gallons (million)
1924	Pumped to Randwick Reservoir	191
1926	Pumped to Randwick and Waverley Reservoirs	825
1928	" " " "	2,007
1930	" " " "	2,666
1932	" " " "	2,746
1934	" " " "	2,220
1936	" " " "	2,774
1938	" " " "	3,154



PENSHURST RESERVOIRS.

No. 1 Steel: 1 million gallons.
No. 2 Steel (elevated): 1½ million gallons.
No. 3 Reinforced Concrete (elevated): 2 million gallons (under construction).

The pumping station at Carlton was commenced in 1891 by the installation of a gas engine in a small structure erected on land rented from the Railway Commissioners at Webbers Road, Carlton. The engine was operated by the local Turncock and its duty was to pump water which gravitated from Petersham Reservoir to the Illawarra Suburbs into a 20,000 gallons cast iron tank erected on brick piers at Penshurst for supply to the higher portions of Kogarah and Hurstville. In 1893, a Blake Duplex pump, capacity 12,000 gallons per hour, formerly in use at the old North Shore pumping station, superseded the gas engine, which then remained as a standby until it was sold in 1900.

In 1896, a steel reservoir with a capacity of 1,000,000 gallons having been erected at Penshurst and a 12-inch rising main laid thereto from Carlton to meet the increasing demands of the higher levels of Kogarah and Hurstville, an additional pump of the Worthington direct-acting type, with a capacity of 30,000 gallons per hour, was installed. In 1909, the Blake pump was replaced by a second Worthington pump. A new boiler transferred from the dismantled Menangle Scheme was also erected and the pump house practically rebuilt. In 1914, a second steel reservoir (capacity 1½ million gallons) having been erected at Penshurst, the Carlton plant was added to by a new boiler and the Morts Dock engine and pumps, transferred from Crown Street pumping station. The two Worthington pumps were retained as a standby plant.

In 1919, a 20-inch suction main to the Carlton pumps was laid from the new 30-inch Rockdale main and a 15-inch rising main from the pumps to Penshurst Reservoir was completed. In order to provide a duplicate plant equal to any emergency, a four stage Thompson centrifugal pump direct coupled to a high speed compound engine was also installed.

The system of supply mains which had followed the areas of greatest settlement, reached Penshurst by a roundabout route, and by the time augmentation of supply was required, the use of a much more direct line of supply was desirable. In 1919, therefore, action was taken to establish a new pumping station at Lakemba to take over the duty hitherto carried out at Carlton. This was completed in April, 1924, and from the time that this station came into regular use, the Carlton station has been operated only on occasions of peak demand. Since 1933, following the further equipment of Lakemba and the completion of the 30-inch rising main from that station to Penshurst, Carlton station has been retained only for emergency use until the independent supply from Woronora Dam is available to Penshurst. The maximum amount of water pumped from it in any year was 902 million gallons (in 1922-3).

The plant at Lakemba is electrically driven and consists of:—

(i) Two sets of Metropolitan Vickers synchronous induction motors 2,200 volt 450 B.H.P. direct coupled to centrifugal

pumps complete with transformers from 10,000 volts and automatic starters (press button control). In 1938, the pumps were replaced by more efficient Thompson pumps, using the existing motors.

(ii) A Metropolitan Vickers 415 volt 600 B.H.P. motor fitted with transformer from 10,000 volts direct coupled to a 16-inch two stage Thompson pump (added in 1930 to take the peak load).

(iii) Two 415 volt, 102 B.H.P. motors each with transformer driving a Briton centrifugal pump. (Added in 1930 to pump to the reservoir at Canary Road, Canterbury). In 1938, these pumps were replaced by two Thompson centrifugal pumps of more efficient type, using the existing motors.

A 30-inch suction main was laid in 1923 along Cornelia Street, Lakemba, from the Potts Hill-Illawarra trunk main to supply the pumps and a 24-inch rising main from the pumping station to Penshurst Reservoir. In 1930, the first section of a 30-inch cement lined steel rising main, replacing in part the existing 24-inch main, was laid to Canary Road and a 15-inch cement lined cast iron rising main was laid to East Hills. In 1933, the 30-inch steel rising main was completed to Penshurst.

The quantity of water pumped annually from this station has now grown to 2,091 million gallons.

Service Reservoirs.

Service reservoirs are provided to cope with hourly variations in the local demand and to ensure supply over any short period that the trunk mains, either by accident or for repairs, cease to function.

They are naturally always situated at the highest points available, so as to command the widest territory and they are of two broad types—elevated and non-elevated. The latter are sometimes covered and sometimes left open. The materials of their construction have varied with the progress of engineering science, so that practically all kinds and shapes may be seen in the Sydney system—cast iron, wrought iron, mild steel, concrete and reinforced concrete. Modern practice now favours the last mentioned material.

The basis of storage aimed at in Sydney is two maximum days' supply for the area tributary to any reservoir at surface level. In certain cases, where the possibility of interruption to supply is remote, one day's supply has been allowed for elevated reservoirs which are much more costly than those of equal size on the surface.

As development extends and population increases, additional service reservoirs become necessary. This is one of the never ending problems of supplying water to a great Metropolis, particularly where its topography is so broken as that of Sydney and its suburbs. This is illus-

trated by the fact that in 1898 there were only 10 service reservoirs in the southern system. In 1908 these had grown to 13; in 1918 to 22; in 1928 to 25, and in 1938 there were 30.

The following is a list of the service reservoirs erected from time to time in the Southern system:—

Year erected	Situation	Type	Capacity	T.W.L. above Sea Level	Depth
1859 ..	Crown Street	Brick (covered)	3,250,000	141	15′
1864 ..	Paddington[a]	Brick and Concrete	2,000,000	214	16′ 6″
1880 ..	Woollahra	Brick	1,000,000	282	18′
1887 ..	Petersham	Brick (covered)	2,157,000	166	26′ 9″
1887 ..	Waverley No. 1	Concrete and Brick (cov.)	1,087,000	360	19′ 9″
1888 ..	Ashfield No. 1[b]	Wrought Iron	100,000	223	16′
1891 ..	Liverpool Dam[c]	Earthen and Conc. Face	37,000,000	254	17′
1891 ..	Penshurst[d]	Cast Iron (Elevated)	22,800	270	5′
1894 ..	Waverley, H.L.[e]	Concrete	40,000	380	5′
1895 ..	Penshurst No. 1	Steel	1,000,000	270	33′ 2″
1895 ..	Smithfield No. 1	Concrete	100,000	178.5	17′
1899 ..	Centennial Pk No. 1	Brick and Concrete (cov.)	18,000,000	245	20′ 6″
1901 ..	Liverpool (Mt. Misery)	Reinforced Concrete	250,000	207	15′ 3″
1904 ..	Vaucluse	Concrete	1,000,000	313	17′ 7″
1910 ..	Randwick	R. Concrete (covered)	1,500,000	275	28′ 4″
1910 ..	Drummoyne	Steel (Elevated)	1,000,000	168	31′
1910 ..	Penshurst No. 2	Steel (Elevated)	1,500,000	300	38′ 6″
1910 ..	Bellevue Hill	Steel (Elevated)	400,000	380	14′
1912 ..	Ashfield No. 2	Steel (Elevated)	1,000,000	260	39′ 2″
1915 ..	Balmain	Rock and Conc. (covered)	2,376,250	128	18′ 6″
1917 ..	Waverley No. 2	Concrete (cov.)	4,260,000	360	18′ 8″
1917 ..	Waverley, H.L.	R. Concrete (Elevated)	500,000	396	14′

[a] Not in use since 1898. Site sold to Paddington Council in 1934.
[b] Transferred to Holroyd, 1916.
[c] Transferred to Campbelltown, 1914.
[d] Altered to present size in 1933.
[e] Superseded, 1917.

Year erected	Situation	Type	Capacity	T.W.L. above Sea Level	Depth
1920 ..	Bankstown	R. Concrete (Elevated)	964,000	280	28′ 7″
1925 ..	Smithfield No. 2	R. Concrete	580,000	178.5	17′ 10″
1925 ..	Centennial Pk No. 2	Concrete (cov.)	19,900,000	245	20′ 3″
1929 ..	Canary Road	R. Concrete (Elevated)	1,027,000	271.5	30′ 9″
1929 ..	North Bondi	Concrete (cov.)	19,000,000	245	20′ 8″
1930 ..	Vaucluse, H.L.	R. Concrete (Elevated)	250,000	400	30′
1931 ..	Engadine	R. Concrete	500,000	654	20′
1935 ..	East Hills	Reinforced Conc. (Elev.)	1,000,000	230	30′
1936 ..	Randwick Sth	Conc. (Elev.)	1,013,000	210	30′
1936 ..	Sutherland	Concrete	1,070,000	352	18′
1938 ..	Penshurst No. 3	R. Concrete	2,012,000	300	30′
1938 ..	Waverley No. 3	R. Concrete	15,000,000	359.67	25′

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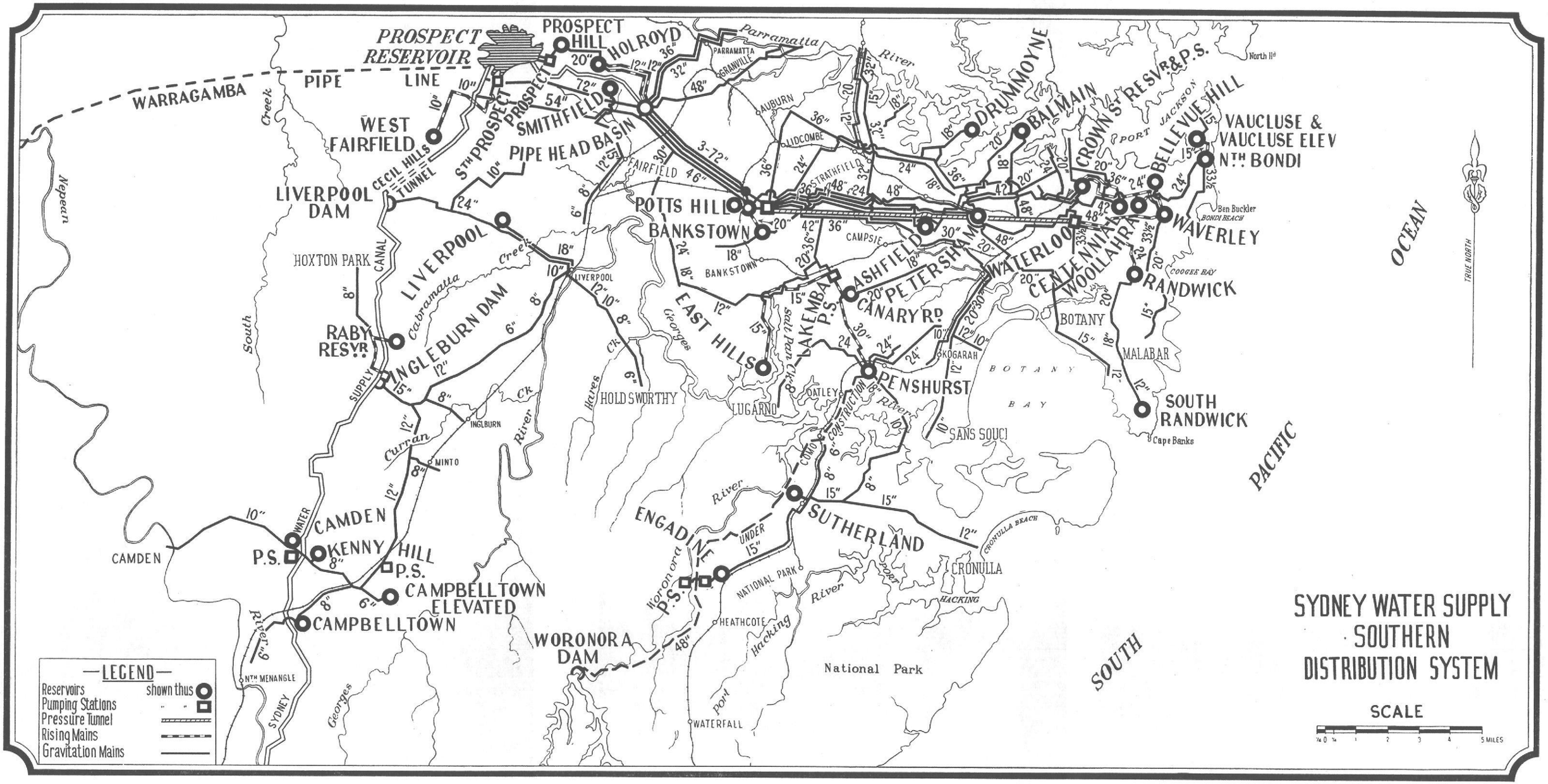


SYDNEY WATER SUPPLY SOUTHERN DISTRIBUTION SYSTEM

CHAPTER XI

UPPER NEPEAN SCHEME—DEVELOPMENT SINCE 1888

NORTHERN DISTRIBUTION SYSTEM—(METROPOLITAN)

When the Board took over the water supply from the City Council in 1888, such portions of North Sydney (or North Shore as it was then called) as could be served by gravitation were supplied by a 9-inch cast iron submarine main from Dawes to Milson's Points, conveying water from Paddington Reservoir. Early in 1888, to meet urgent requests for supply to the higher levels of North Sydney, the Board established a temporary pumping station at a cost of £1,080 at Junction Street, North Sydney, 125 feet above H.W.M. A pair of Blake duplex direct-acting pumps, supplied by Morts Dock, were installed, capable of pumping 10,000 gallons per hour through a 6-inch rising main to two 20,000 gallon wrought iron tanks, erected in the grounds of St. Thomas' Church, with top water level of 325 feet. This station was dismantled in 1892, when the supply from Ryde Pumping Station became available, the pumps being transferred to Carlton Pumping Station and the tanks later on to Wahroonga. The submarine main remained until 1917 when it was abandoned. Up to that time it was used intermittently during summer to supply the lower levels of North Sydney. In the early years, the main was damaged on occasions by vessels dropping their anchors on it.

To supply adequately the large territory on the northern side of the Harbour, it was necessary to establish a pumping station on the north side of Parramatta River, with direct connection either to Potts Hill or Pipe Head. Accordingly, in 1892, the Public Works Department completed and handed over to the Board a scheme based on supply between Potts Hill and Ryde. The trunk main consisted partly of 24-inch and partly of 20-inch cast iron pipes, and delivered the water into a balance reservoir near Ryde Railway Station. Here a pair of powerful pumps raised the water through a 24¾-inch wrought iron rising main into a 1,000,000 gallon wrought iron tank at Ryde Hill at a level of 234 feet above H.W.M., and by a continuation of the same main, into a pair of 1½ million gallon wrought iron tanks at Chatswood at an elevation of 370 feet above H.W.M. From the first-named tank the whole of Ryde, Gladesville and Hunters Hill was supplied, a 9-inch branch extending over the Parramatta River and Iron Cove Bridges carrying the supply

to the heights of Balmain. The tanks at Chatswood afforded supply to Willoughby, North Sydney and Mosman.

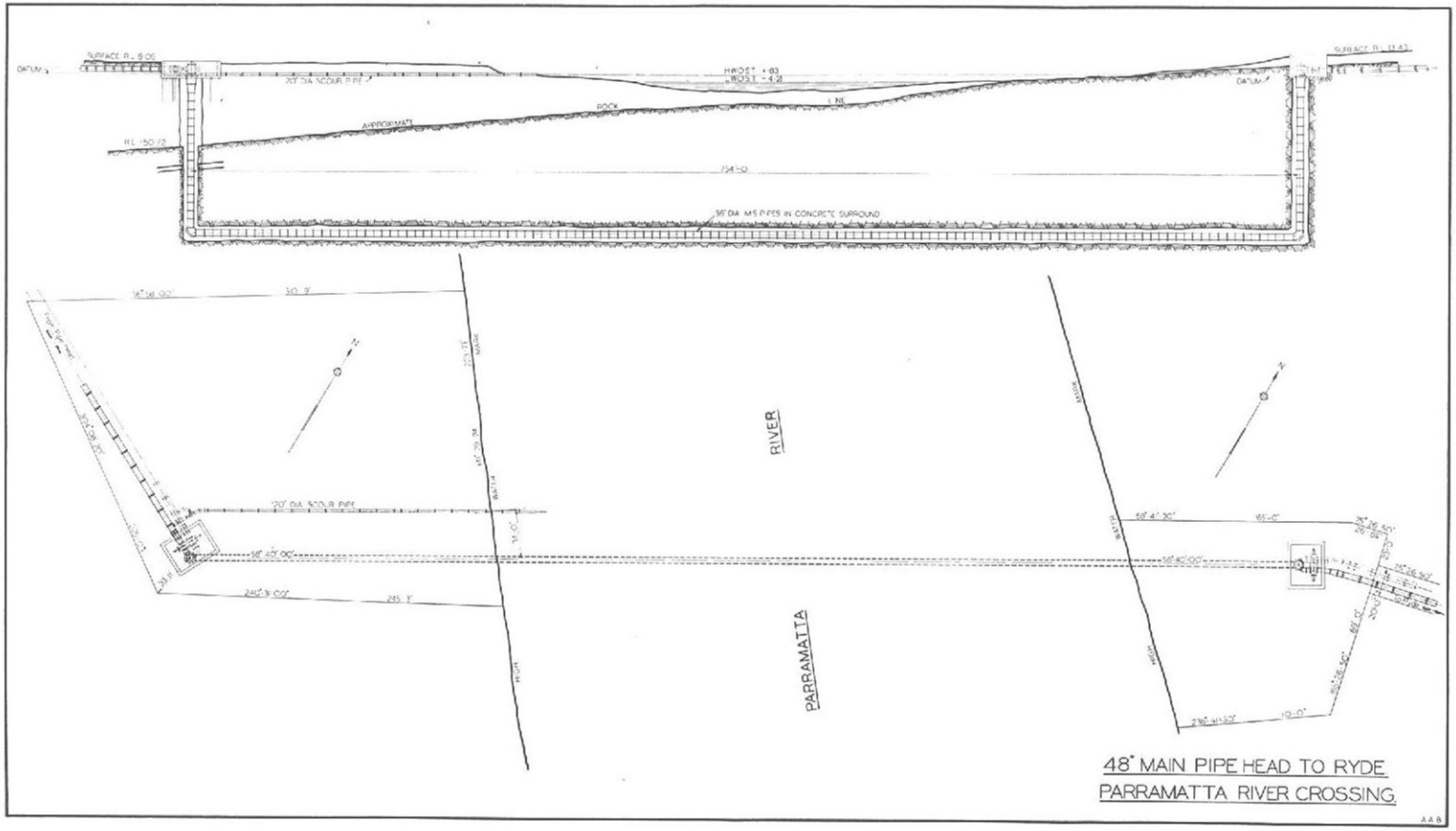
By 1895, the districts between Chatswood and Hornsby had shown considerable development following the construction of the railway from Milson's Point, and it became necessary to supply them with water. Land was purchased on what is now the Pacific Highway at Wahroonga, and the two 20,000 gallon tanks transferred from the old North Shore Pumping Station and erected at a height of over 720 feet above sea level. A pumping station was established at Chatswood Tanks and the pumps originally stationed at the old Woollahra Pumping Station taken over from the City Council were installed, together with a new boiler. A further pump was added in 1897 to meet increased demands, a new steel tank of 1,000,000 gallons capacity being likewise completed at Wahroonga in the following year, the existing tanks being retained for the supply of the adjacent high level zone. The water was pumped to the Wahroonga Tanks through a 10-inch steel rising main, 7½ miles in length. This main was extended as a distributary main to Hornsby Township, an 8-inch steel branch therefrom supplying Thornleigh, Beecroft, etc. About 14 miles of reticulation mains served to meet immediate requirements of these new districts.

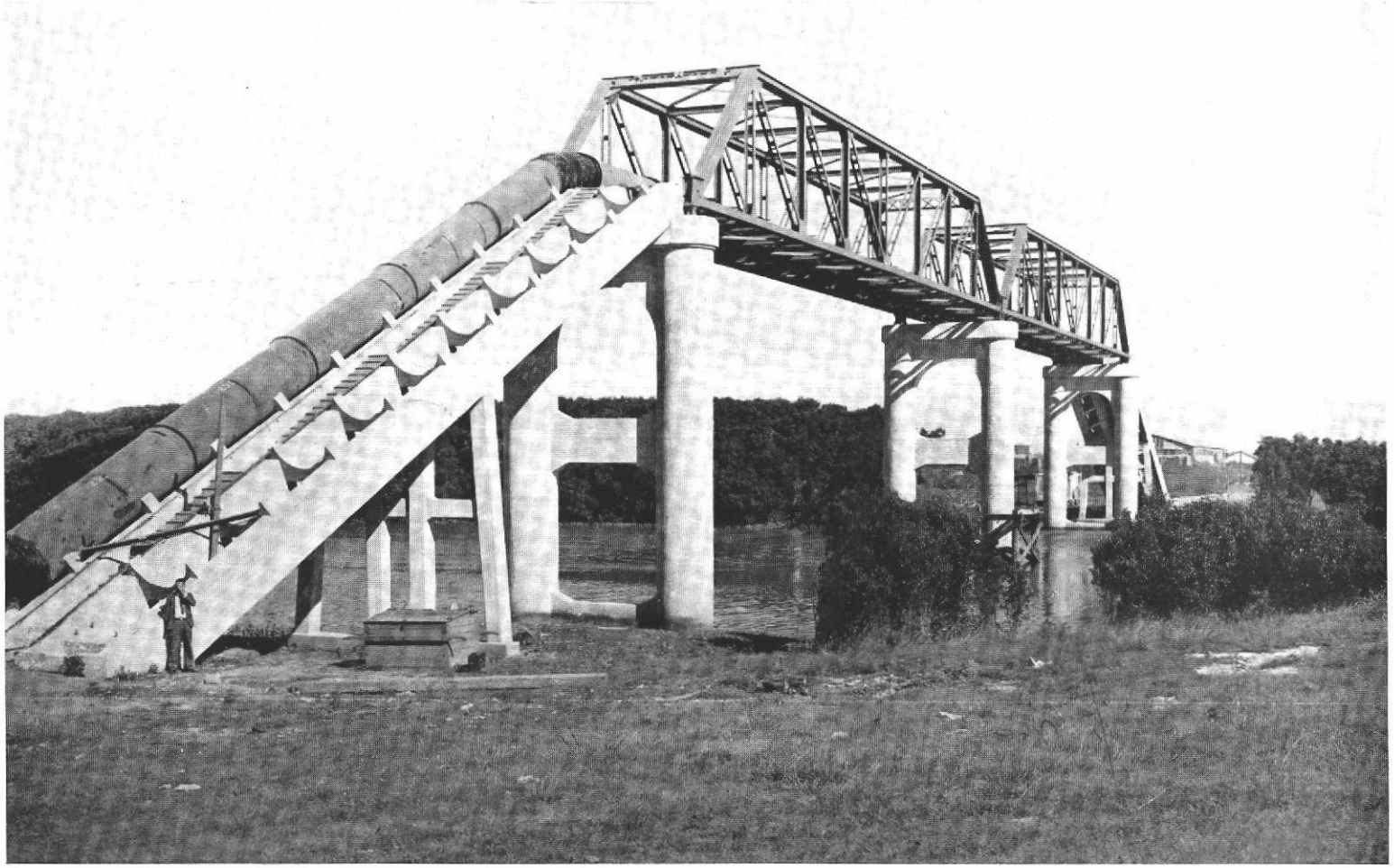
In 1900, a reservoir with a capacity of 500,000 gallons was constructed at Pymble to serve the districts between Chatswood and Pymble and reduce the abnormal pressure due to supply from the much higher Wahroonga Reservoir.

In 1901, a 30-inch steel rising main was laid from the pumping station at Ryde to Ryde Hill Reservoir, with a connection en route to the 24¾-inch rising main to Chatswood to enable the two reservoirs to be separately served from the pumping station.

By 1903, the 24-inch-20-inch trunk main from Potts Hill to Ryde had become unreliable and supplied insufficient suction water to the Ryde Pumps. To meet this position, a 32-inch steel main, partly riveted and partly locking bar pipes, was laid from Pipe Head Basin to Ryde, the latter pipes being those purchased for the Penrith Emergency Scheme in 1902. The 24-inch-20-inch main was then relegated to the position of a distribution main to Concord, Homebush, etc.

By 1905, the 10-inch steel pumping main from Chatswood to Pymble, Wahroonga, Hornsby and Beecroft, etc., had become extensively pitted and as its failure would have meant that the whole of these districts would have been deprived of water, a 15-inch pumping main was laid in that year from Ryde Pumping Station to Wahroonga to supersede the arrangement whereby the water was pumped from Ryde to Chatswood and thence to Wahroonga, and a 12-inch rising main was laid from Chatswood pumps to Pymble and connected with this 15-inch main so that an alternative source of supply to districts between Chatswood


SURFACE R.L. 8.05
DATUM
20' DIA SCOUR PIPE
HWOST +.83
LWOST -4.2
SURFACE R.L. 11.43
DATUM
APPROXIMATE
ROCK
L.W.L.
R.L. -50.72
734'-0"
36" DIA M.S. PIPES IN CONCRETE SURROUND
RIVER
PARRAMATTA
20' DIA SCOUR PIPE
98° 40' 00"
240' 9" (OS)
245' 5"
98° 41' 30"
181'-0"
101° 40' 00"
240' 11" (OS)
10'-0"
48" MAIN PIPE HEAD TO RYDE
PARRAMATTA RIVER CROSSING
A.A.B.



48″ MAIN, PIPE HEAD–RYDE. BRIDGE CROSSING PARRAMATTA RIVER.

and Hornsby would be available. The old 10-inch steel main was used for some years longer as a distributory main.

In 1908, the equipment at Ryde Pumping Station was supplemented by the addition of five Stirling boilers with chaingrate stokers and superheaters, and two sets of Parsons turbo-centrifugal pumps, all of which had been originally purchased for the Penrith Emergency Scheme. Coal bunkers having a capacity of 1,000 tons, together with a coal conveying and ash handling plant, as well as a Green's economiser, were also installed. The new pumps took over the duty of pumping to Wahroonga and Pymble Reservoirs, relieving the Chatswood plant, which was then retained for use as a standby for the Ryde pumps until 1918, when, there being a sufficient number of service reservoirs between Chatswood and Hornsby and between Ryde and Hornsby which could be supplied direct from Ryde, the station was dismantled.

The problem of keeping up the supplies to the Ryde pumping station to meet the ever increasing demands made upon it was tackled in much the same way as was that of keeping up the supplies to Crown Street Reservoir, in the southern system. By 1911, the 36-inch main from Pipe Head to Ryde was becoming inadequate to cope with the summer demand without boosting and in that year, two Robinson centrifugal pumps, 18-inch and 15-inch respectively, direct-coupled to Robinson vertical compound tandem jet condensing engines, were installed at Pipe Head for this purpose, the 18-inch pump delivering 7,000 gallons per minute with 35 feet head and the 15-inch pump 5,000 gallons per minute with 30 feet head. The boiler plant consisted of two 5-ft. x 12-ft. and one 6-ft. x 13-ft. vertical boilers. In 1914, this plant was augmented by the addition of three Wolff locomobile engines geared to three 6-inch Gwynne centrifugal pumps each capable of delivering 6½ million gallons per day against a head of 180-feet. In 1916, the 32-inch main, which had developed many weaknesses between Pipe Head and Parramatta, necessitating enveloping the faulty pipes in concrete reinforced with steel bands and recaulking the joints, was supplemented by a 36-inch cast iron main, and thereafter further boosting became unnecessary, and the boosting plant was transferred elsewhere.

In 1924, to provide additional supply to Ryde Pumping Station, the construction of a third line of pipes, 48-inches in diameter, was commenced, following as direct a line as possible between Pipe Head and Ryde and crossing the Parramatta River. Two alternative means of crossing were considered, viz., a tunnel and a bridge, the former being ultimately decided upon. By 1925, the pipe line was completed except for the crossing and, as it had become urgently necessary to augment the supply to Ryde Pumping Station, a temporary connection was made by 510 yards of 20-inch continuous woodstave pipes through bad ground on the southern side of the river and 144 yards of 18-inch flanged steel

pipes laid in trench in the river bed. The 18-inch pipes developed serious faults in a few months, which examination revealed to be due to rapid corrosion. They were therefore replaced with 20-inch woodstave pipes but these in turn quickly proved unsatisfactory. Finally two lines of 10-inch ball and socket cast iron pipes and one of 20-inch flanged steel pipes specially protected against corrosion were substituted.

Borings for the proposed tunnel across the river having been completed by the Mines Department, shaft sinking in connection with the tunnel was commenced in the latter part of 1926, and the final section of the 48-inch main above ground was laid across the swamp on the southern side of the river to the commencement of the tunnel crossing. By the end of 1928 the tunnel and shafts had been completed and lined with concrete, and connection made to the main on both sides of the river.

On the tunnel being placed in service, defects developed which necessitated its being unwatered and on examination, serious ruptures were found to have taken place. Some months were spent in sealing off the inflow of river water by grouting, and this was finally reduced from 35,000 gallons to 600 gallons per hour. It became clear that the inflow could not be permanently stopped without more drastic treatment. It was accordingly decided to insert an inner lining in the tunnel and shafts of 36-inch flanged steel cement lined pipes and completely fill in the space between the tunnel and the steel lining with blue metal concrete. This work was completed in 1929. Although the diameter of the tunnel connection was thus reduced compared with the original design, the change over which had meanwhile taken place from the old pumping station to the new pumping station at Ryde offset this and the delivery capacity of the trunk main as a whole remained practically as originally calculated. While the work of lining the tunnel was being carried out, an additional temporary line of 20-inch steel pipe was laid across the river bed and connected to the 48-inch main on both sides.

The original conception of the tunnel crossing of this pipe line and the remedial measures adopted were two of the matters which came under review by the Royal Commission referred to in the previous chapter and its report contained criticism of both the original and the remedial work. The Commission considered that the failure of the tunnel was due to faulty location, which provided insufficient cover to withstand the bursting pressure of the water, and if in the first place a more reliable estimate had been furnished of its cost, it would have been apparent that the alternative proposal for a bridge was a more satisfactory project than a tunnel. The remedial measures were criticised on the score of the reduction of the size of the conduit, the Commission considering that less expenditure would have been incurred had

the tunnel been entirely abandoned after it failed and one of the original bridge alternatives adopted.

The Board, in reply, stated that the failure of the tunnel under test was due to inherent faults general in the Hawkesbury sandstone underlying the metropolitan area and pointed out that no previous experience was available as to the behaviour of this rock formation under water pressure. Further, the tunnel scheme was adopted as cheaper than the bridge alternatives on the basis of estimates submitted at the time the scheme was adopted, and although the actual cost largely exceeded the estimate, this was due to difficulties which could not be foreseen and similar or other difficulties arising from the abnormally bad ground might have rendered the bridge alternative more costly than estimated if it had been adopted. So far as the remedial measures adopted were concerned, the Board considered these to be justified by reason of their constituting the most speedy and practical solution of the very urgent problem of ensuring the safety and adequacy of the water supply to the Northern Suburbs. They met the essential need of preventing a water shortage throughout these suburbs during the summer of 1929-30.

The provision of a second 48-inch pipe crossing of the Parramatta River was commenced at the latter end of 1935, and completed in October, 1936, the site chosen being at Thackeray Street, in the Municipality of Ermington and Rydalmere. In this case, a bridge was used constructed in reinforced concrete and steel, and under arrangement with the local council, which made a contribution to meet the additional cost, carries a footway for pedestrian traffic. The pipe line is of electrically welded steel. This duplicate pipe crossing will eventually form portion of a second 48-inch pipe line, a section of which has already been commenced.

The trunk mains supplying the water to Ryde Pumping Station for the Northern Suburbs are therefore at present one 32-inch pipe line laid in 1904, one 36-inch pipe line laid in 1916, one 48-inch pipe line laid in 1924-29, and a duplicate 48-inch pipe crossing over Parramatta River added in 1936.

The original equipment of the Ryde Pumping Station and the additions made in 1908 have already been described. In 1909 a 20-inch cast iron rising main was laid from the station to the Hermitage Reservoir, Ryde, which had just been completed, and in 1912 a third Parsons turbo set, direct coupled to three Worthington 8-inch centrifugal pumps, was added to the plant.

By 1916, it was apparent that it would not be possible to provide much longer in the existing station for the ever increasing demand and it was decided to construct a second and larger station on land which was acquired for the purpose on the eastern boundary of the old station. The new station was completed in July, 1921, and formally put into commission on 15th September, 1921, by the Minister for Public Works

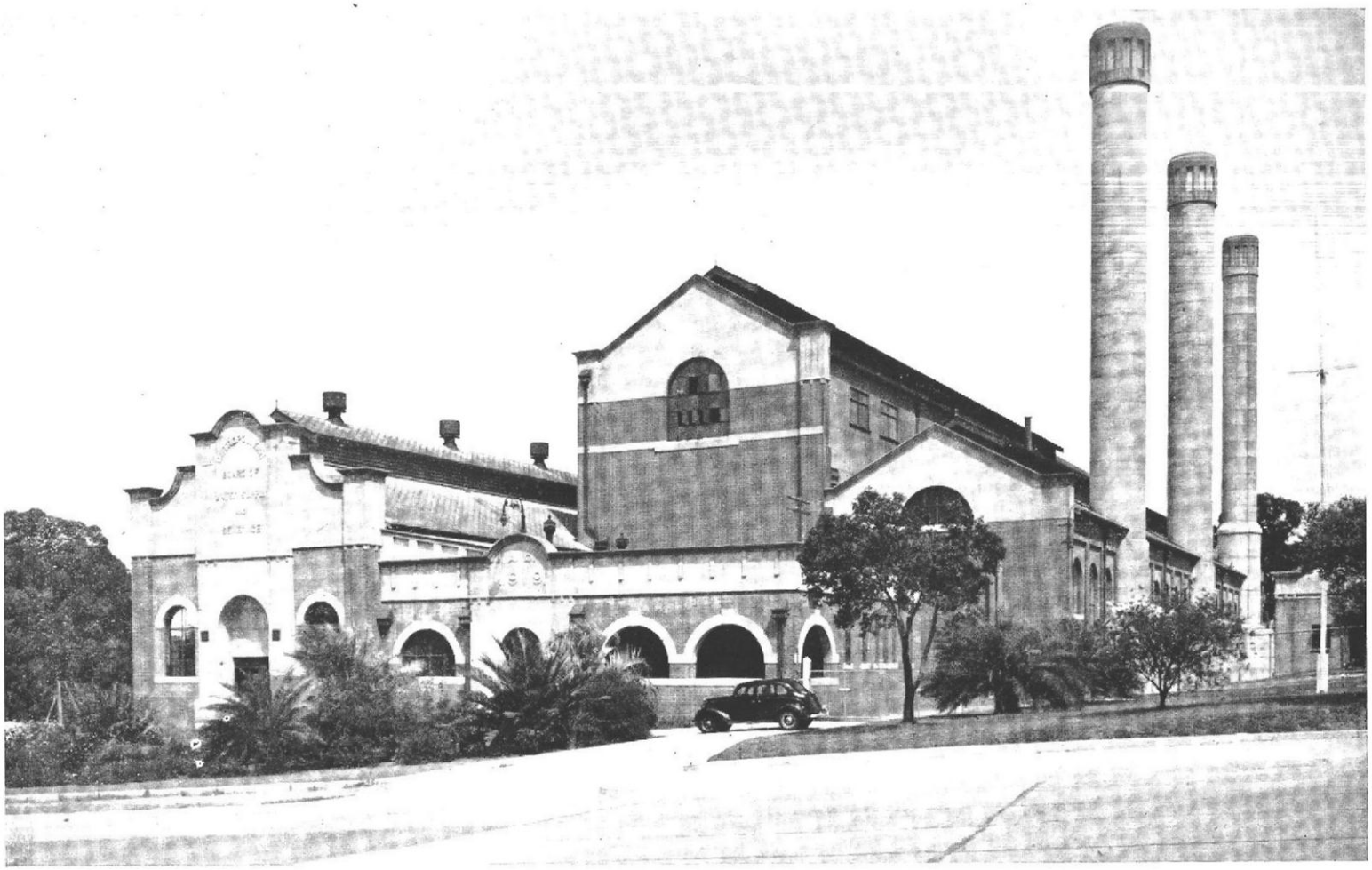
(Hon. John Estell, M.L.A.). In the meantime an Allen triple expansion surface condensing engine generating set, providing current for motors which drove a Thompson centrifugal pump and a fourth turbo set (Willans and Robinson) direct coupled to a 12-inch 4-stage centrifugal pump, were added in 1916 to the machinery of the old station, while a separate steel rising main (28-inch) was laid from it to Pymble Reservoir to enable the latter to be served independently, and a 20-inch steel rising main to the reservoir at Mobbs Hill (completed in 1916), which was extended in 1918 in 24-inch steel pipes to Beecroft and Wahroonga Reservoirs, superseding the 15-inch Ryde-Wahroonga rising main which had become too small.

Following its completion, the new station took over the pumping to Chatswood and Pymble Reservoirs, leaving the old station to confine its pumping mainly to Hermitage, Mobbs Hill, Beecroft, and Wahroonga Reservoirs. In 1927, owing to the worn-out condition of all the plant thereat excepting the No. 4 turbo set, the duty of pumping to the two Hermitage Reservoirs was also transferred to the new station and the No. 4 turbo set was removed thereto. Finally the old station ceased to operate in 1930, and the remaining plant was sold at auction. The building which housed the pumps is now used as a store.

The first installation of the new station consisted of four Willans Robinson steam turbines and 18-inch multi-stage type centrifugal pumps for pumping to Chatswood and Pymble Reservoirs, the output of the two Chatswood units being 5,400 minute gallons each against a head of 450 feet, and of the two Pymble units 5,500 gallons each against a head of 600 feet. Parsons turbo-alternators (300 k.w.) were provided for lighting and auxiliary power, with the necessary switch gear and other accessories. Pneumatic coal and ash handling plant was added in 1923.

In the same year a 30-inch rising main from Ryde Pumping Station to Chatswood Reservoirs was laid in substitution of the old $24\frac{3}{4}$-inch rising main, which was in a very frail condition. The lower end of the new main, consisting of riveted steel pipes, had been laid as far as Ryde Hill Reservoir some twenty years earlier (see page 111), but as a tram-line had subsequently been laid over it and trouble was experienced with the joints under the line, these pipes were lifted, recoated and laid along a new route as far as Hattons Flat. (This section of the line was taken up and replaced with 30-inch spirally welded steel pipes in 1936.) The remainder of the line was laid in new cast iron pipes.

In 1928, new units to take up the duty of pumping to Hermitage Reservoirs in place of the worn-out unit at the old pumping station were installed. These consisted of two sets, each comprising a Fraser-Chalmers turbine 900 B.H.P. direct connected to single stage Kelly and Lewis centrifugal pumps with bifurcated 20-inch suction and 18-inch delivery, designed to supply 6,944 gallons per minute against a head of



RYDE PUMPING STATION (ERECTED IN 1921).

WAHROONGA NO. 3 RESERVOIR. CAPACITY TEN MILLION GALLONS. COMPLETED IN 1937.

320 feet. Each set included a condenser of the "contraflo" service type with turbine driven condensate pump. The station building was considerably enlarged to provide accommodation for a new unit for Mobbs Hill, Beecroft and Wahroonga pumping, and for the No. 4 unit to be transferred from the old station. In 1928, a 24-inch welded steel cement lined rising main was laid from the station to Mobbs Hill Reservoir, making with the existing 20-inch rising main a second method of supply to that point, and by connection to the existing 24-inch rising main between Mobbs Hill, Beecroft and Wahroonga, enabling any one of the latter two reservoirs to be supplied simultaneously with Mobbs Hill.

A 30-inch electrically welded cement-lined steel rising main was laid in 1929 from the 28-inch Ryde-Pymble rising main at de Burgh's Bridge over the Lane Cove River to Killara Reservoir, to enable the Ryde pumps to supply that reservoir, and later this 30-inch main was continued from the bridge to the pumping station. The 28-inch rising main in this section then became part of the Ryde-Killara rising main, and the newly-laid 30-inch main part of the Ryde-Pymble rising main. In 1929 also, a new unit for pumping to Mobbs Hill and Wahroonga was provided, consisting of a Metropolitan Vickers steam turbine of 1,500 B.H.P., direct coupled to a 15-inch Thompson two stage centrifugal pump, having a capacity of 10 million day gallons to Mobbs Hill (head 515 feet), or 6 million day gallons to Wahroonga (head 853 feet).

Also in 1929, in order to provide additional steam generating plant to supply the new unit then installed for pumping to Mobbs Hill and Wahroonga, and the No. 4 turbo centrifugal set which it was proposed to transfer from the old station to the new station, a contract was let for a Kidwell boiler (4 drums) with a capacity of 40,000 lbs. per hour at 250 lbs. per sq. inch pressure and 200 degrees superheat, complete with forced draught, Frederick stoker, economiser, and superheater; a reinforced concrete chimney 113 feet high 7 feet diameter was built to connect to the new boiler. When the boiler was put into operation, difficulty was experienced owing to the formation of large clinkers on the brickwork and in the removal of ashes sumped from the ashpit. A new design of ash pit was put in, but this did not remove the root cause of the trouble, which was found ultimately to lie in the stoker. The contracting company, in due course, agreed to substitute a travelling grate stoker, and to allow credit for the Frederick stoker at the original cost to the Board, and a contract on this basis was accepted in October, 1934. Since its installation the boiler has operated satisfactorily. Shortly afterwards to provide for the increased consumption in the zone supplied from Pymble Reservoirs, and in the expectation that economy would require that future extensions should be electrically operated, two electro-centrifugal pumping units, each consisting of a 3-stage 20-inch centrifugal pump with a capacity of 12 million day gallons against a

head of 596 feet direct coupled to 2,000 B.H.P. motor, 10,000 volt A.C. drawing energy from the City (now County) Council's system, were installed. The two pumps on test failed by substantial margins to reach the guaranteed efficiencies, and as the contractors were unsuccessful in their efforts extending over about two years to bring their performance up to the stipulated standard, and went into liquidation before the matter was satisfactorily adjusted, the Board retained the pumps and the balance unpaid on the contract. These units now operate as stand-by plant. Two of the steam driven pumps were reconstructed, and their efficiency and output increased to an extent which enabled the position brought about by the inefficiency of the electric pumps to be met for a few years ahead.

In 1935-6, a comprehensive investigation was carried out by the Engineer-in-Chief (Mr S. T. Farnsworth) to determine the relative economies of steam as compared with electrical operation, and the balance of advantage being found to be with the former, it was decided by the Board on 18th June, 1937, to make any further additions or alterations to the station on this basis. Since then a contract has been let for further plant consisting of two Babcock and Wilcox Water Tube boilers, each with an evaporative capacity of 25,000 lbs. of steam per hour at a pressure of 250 lbs. sq. inch and a temperature of 625°F, one 1,300 B.H.P. Metropolitan Vickers turbine gear driving, one two-stage 15-inch Thompson's pump with a capacity varying between 11 million gallons per day at 380-feet head and 5 million gallons per day at 750-feet head, and four 750 B.H.P. Metropolitan Vickers turbines gear driving, four two-stage 12-inch Thompson pumps each with a capacity varying between 7 million gallons per day at 280-feet head and 2·4 million gallons per day at 750-feet head, which when installed will take up the duty of pumping to Mobbs Hill, Beecroft, Wahroonga, Killara and Pymble Reservoirs as required.

A second line of 30-inch rising main was laid in 1936 from Ryde Road near de Burgh's Bridge to Pymble Reservoir, and a welded steel rising main of similar diameter, direct from Ryde pumps to the large additional reservoir recently completed at Wahroonga, together with a 15-inch connection to Pymble Reservoir.

Until 1935 water had been delivered to the elevated reservoir at Wahroonga by putting additional pressure on the pumps at Ryde and the rising main. In that year, a small automatic pumping plant was installed at Wahroonga No. 1 Reservoir to deliver from that storage into the Elevated Reservoir, thus enabling a steady pressure to be maintained at the Ryde pumps, and avoiding the frequent operation of valves at Wahroonga.

The following statement showing the quantity of water pumped from Ryde Pumping Station to the service reservoirs supplying the Northern Suburbs, will serve to illustrate the large increase in the consumption over quinquennial periods:—

	From Old Pumping Station	From New Pumping Station	Total
	gallons	gallons	gallons
1892	192,166,000		
1897	464,817,000		
1902	761,411,000		
1907	1,103,792,000		
1912	2,248,663,000		
1917	2,489,877,000		
1922	2,035,587,000	2,069,694,000	4,105,281,000
1927	1,814,155,000	2,853,006,000	4,667,161,000
1932	Closed down	5,948,074,000	5,948,074,000
1937		7,197,381,000	7,197,381,000

Service Reservoirs

The following is a list of the service reservoirs erected from time to time in the northern system. The present number is 25:—

Year erected	Situation	Type	Capacity	T.W.L. Above Sea Level	Depth
1887 ..	Ryde P.S.[a]	Concrete	2,116,000	97	20′
1888 ..	Ryde Hill [b]	Steel	1,000,000	234	22′
1888 ..	Chatswood No. 1	Steel	1,500,000	370	31′ 9″
1888 ..	Chatswood No. 2	Steel	1,500,000	370	32′ 1″
1892 ..	Manly No. 1[c]	Rock and Concrete	946,396	227.83	28′
1896 ..	Wahroonga[d]	Wrought Iron	40,000	717	5′
1898 ..	Wahroonga No. 1	Steel	1,000,000	709.72	25′ 6″
1900 ..	Pymble No. 1	Concrete (Covered)	500,000	567	19′ 6″

[a] Not in use since 1932. [b] Not in use since 1930 (removed to Dural 1938).
[c] Transferred from Manly Council 1904. [d] Superseded 1915.

Year erected	Situation	Type	Capacity	T.W.L. Above Sea Level	Depth
1903 ..	Mosman No. 2[e]	Wrought Iron (Elevated)	72,800	354	17′ 4″
1904 ..	Mosman No. 1	Concrete and Brick (Cov.)	1,925,000	302	20′
1907 ..	Beecroft	Steel	1,000,000	648	32′
1909 ..	Hermitage No. 1	Steel	1,500,000	304.76	38′ 6″
1910 ..	Hermitage No. 2	Steel	1,500,000	304.76	39′
1915 ..	Prospect Hill Tank[f]	Steel	40,000	353.32	10′
1915 ..	Wahroonga No. 2 (High Level)	Steel (Elevated)	250,000	778.83	43′ 6″
1916 ..	Gore Hill[g]	Cast Iron	53,000	347	8′
1916 ..	Holroyd No. 1	Wrought Iron (Elevated)	100,000	315.91	16′ 10″
1916 ..	Manly No. 2[h]	Cast Iron (Elevated)	13,238	270.83	5′
1916 ..	Mobbs Hill No. 1	Steel	1,000,000	459.66	31′ 6″
1917 ..	Hornsby	Steel	1,000,000	672.5	31′
1917 ..	Pymble No. 2	Concrete (Covered)	6,905,160	567	19′ 6″
1924 ..	Bantry	R. Concrete	1,522,000	434.6	31′
1927 ..	Castle Hill	R. Concrete	983,000	468.5	29′ 9″
1929 ..	Holroyd No. 2	R. Concrete (Elevated)	100,000	315.91	15′ 9″
1931 ..	Killara	Concrete (Covered)	36,500,000	425	25′
1934 ..	Prospect	R. Concrete (Elevated)	500,000	450	30′
1934 ..	Mobbs Hill No. 2	R Concrete	1,500,000	459.66	30′
1935 ..	Mt. Colah	Cast Iron (Elevated)	35,000	750	9′
1936 ..	Warringah	Concrete (Surface)	10,000,000	470	20′
1937 ..	Prospect Hill	Concrete	3,000,000	377	20′
1937 ..	Wahroonga No. 3	R. Concrete and Brick	10,000,000	711.75	30′

[e] Not in general use.
[f] Removed 1936.
[g] Removed to Dapto 1920.
[h] Not in use since 1924.

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CHAPTER XII

UPPER NEPEAN SCHEME—DEVELOPMENT SINCE 1888

Country Water Supplies

The problem of supplying water to country centres within the ambit of the Upper Nepean Scheme falls into two divisions:—

(i) The supply of centres far beyond the limits of existing reticulation but adjacent to portion of the Head Works.

(ii) The supply of districts on the fringe of reticulation.

Among the first, have been the Campbelltown, Liverpool, Smithfield, Camden and Ingleburn water supplies; among the latter, the Blacktown-St. Mary's-Riverstone scheme, and the supplies to Horsley Park, Bossley Park and Edensor Park, the Hills District (Castle Hill, Rogan's Hill and Dural). The whole of the schemes in the first group are adjacent to either the Upper or the Lower Canal, and have drawn their initial supplies from those sources. With the steady outward growth of the metropolitan reticulation, they are, however, now being absorbed into the general system. While solely dependent upon supply ex the Canal, their use has, in the absence of any service reservoirs, had to be conditioned by the degree to which adjacent portions of the canal itself could be utilised as a reservoir when remaining portions were undergoing repair, or when supply from the diversion works above was for any reason shut off. While this was not a cause of serious inconvenience in the earlier stages of the Upper Nepean Scheme, it became of greater consequence as the population and demand of the Metropolis grew, and it was necessary to be free to shut off or empty the Canal as occasion demanded without the hampering consideration of its function as a service reservoir to these country schemes. Consequently, in later years, each such scheme was equipped with service reservoirs. The supply to Raby, Austral and Hoxton Park at present under construction will be pumped from the Ingleburn Dam but a service reservoir has been provided to regulate the supply.

Campbelltown Water Supply

The first country town supplied with water by the Board was Campbelltown, in 1888. The supply was taken direct from the Upper Canal at a point 2½ miles distant, the water being conveyed by a 6-inch

cast iron pipe and distributed by reticulation consisting chiefly of 4-inch mains. In 1902, a concrete service reservoir of a capacity of 500,000 gallons was constructed at the offtake from the Canal. In 1913, owing to the urgent demand for water on the higher levels of the town, an oil driven plunger pump was installed within the public reserve to pump to an elevated tank (transferred from Penshurst) on a piece of land acquired by the Board on Convent Hill, and an 8-inch woodstave main was laid from the Canal to supplement the existing 6-inch main. A second pumping unit was added in 1919, comprising a 7 B.H.P. Tangye Oil Engine geared to a horizontal 2 throw bucket pump. In 1922, the original pump and engine were replaced by plant of larger capacity, consisting of a 30 B.H.P. Jelbart horizontal crude oil engine, geared with friction clutch to a Worthington vertical three-throw plunger pump, and in the following year, a 6-inch rising main was laid direct from the pumping station to the elevated tank to enable it to be filled more rapidly. In 1933, the Campbelltown high level system was connected with the Camden system by the laying of an 8-inch cast iron cement-lined main to the high level Reservoir at Kenny Hill (constructed in 1926) and further pumping from the Campbelltown station obviated. In 1935, in order to provide an adequate supply during the periods when the Upper Canal was laid off for repairs, etc., the Campbelltown supply was linked with the Ingleburn-Liverpool system by a 15-inch-12-inch-8-inch trunk main from the newly constructed storage dam alongside the upper canal at Ingleburn. An emergency pumping plant consisting of one 40 H.P. electric motor driving a 5 stage 5-inch Clyde centrifugal pump was also installed to provide supply from this main to Kenny Hill Reservoir during such periods.

Liverpool Water Supply

In the year 1890, the town of Liverpool was supplied with water from the Upper Canal at Cecil Hills. A 9-inch main was laid from the Canal as far as Mt. Young, and thence a 6-inch main conveyed the water to the town. To tide over any possible interruption to the flow in the Canal, a 4 million gallon earthen reservoir was constructed close to the canal from which it is filled. The cost of the original scheme was approximately £13,000.

In 1901, a concrete service reservoir of a capacity of 250,000 gallons, was erected at Mt. Misery, and in 1905 the 6-inch main from the service reservoir was replaced by a 10-inch main. In 1912, the reticulation was extended by the laying of 4,178 yards of 4-inch main, and in the following year, a 24-inch-15-inch wood stave main was laid from the canal to the service reservoir. In 1923, in order to improve the supply to Cabramatta, Canley Vale and Fairfield, a 10-inch main was laid from the trunk main last referred to through these districts. The Liverpool system thus

became linked with the general metropolitan system. During 1924-25, over 5 miles of 6-inch and 8-inch mains were laid in the Liverpool district. In 1933, the reservoir alongside the Upper Canal was cleaned out and greatly enlarged (to 37,000,000 gallons) by raising the earth bank by 10 feet, the upstream face being lined with concrete slabs with bitumen joints.

Smithfield and Fairfield Water Supply

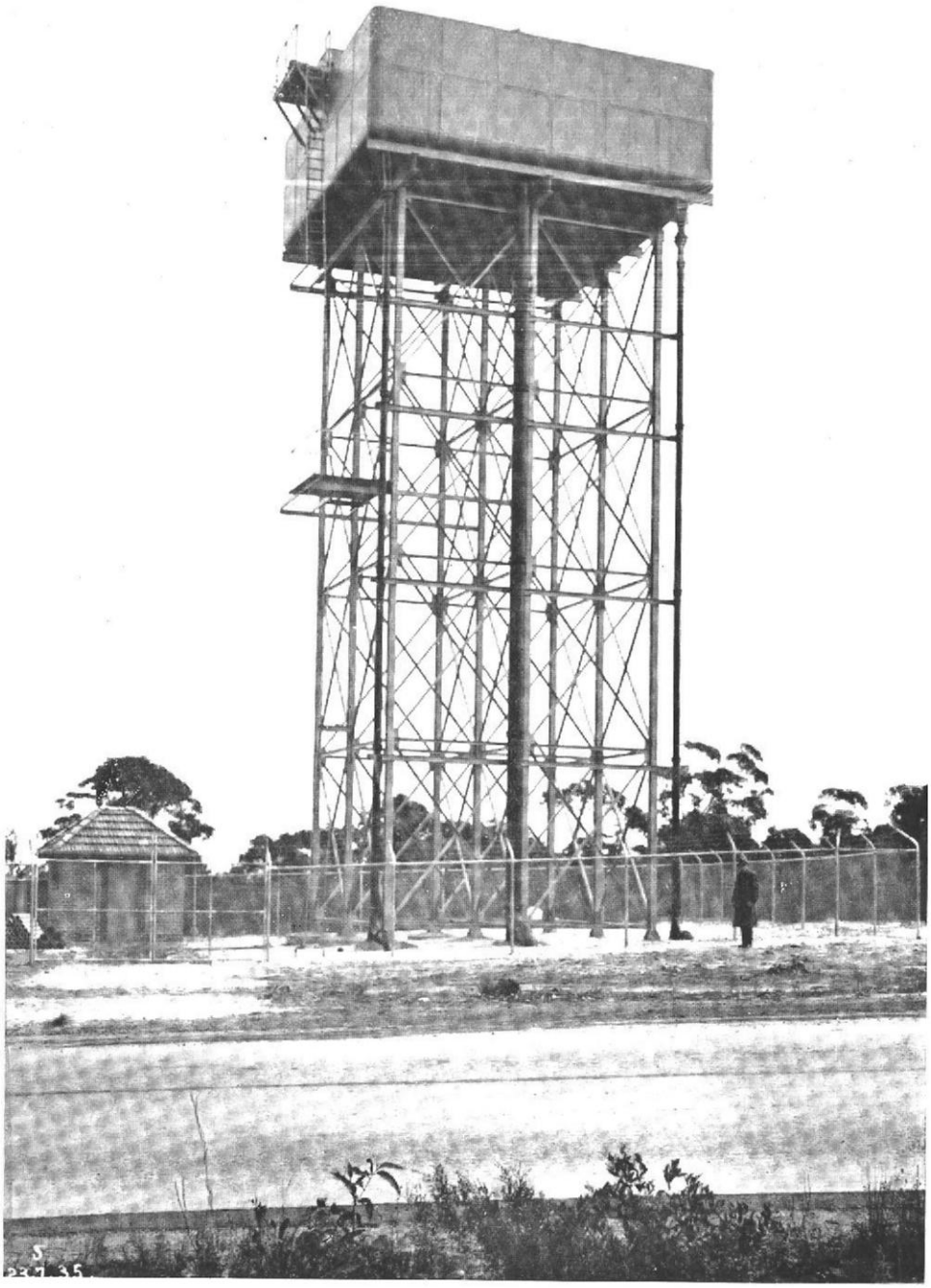
In 1895, a circular concrete tank (Smithfield Reservoir) of a capacity of 100,000 gallons was constructed alongside the Lower Canal, about three miles below Prospect, and a 4-inch (subsequently increased to 8-inch) supply main and $3\frac{1}{2}$ miles of reticulation mains laid to supply a population of about 300 at Smithfield. The works cost about £2,900. In 1913, the reticulation was extended by the laying of 7,974 yards of 4-inch, and 5,919 yards of 6-inch mains, and in 1915, a further 20,000 yards of 4-inch mains were laid, principally to serve market gardens, etc. In 1924, a 15-inch main was laid from Smithfield Reservoir to Fairfield, and thence by 12-inch and 8-inch pipes to Canley Vale, to improve supply to the parts of these districts not affected by the extension from the Liverpool trunk main referred to in the preceding paragraph. A second reservoir was completed in 1925 alongside the original one, consisting of a circular reinforced concrete structure, partly in excavation and partly in bank, of a capacity of 580,000 gallons.

On the completion of the 72-inch main (Upper Canal to Pipe Head) a connection was made in 1937 from this main to the 15-inch supply main.

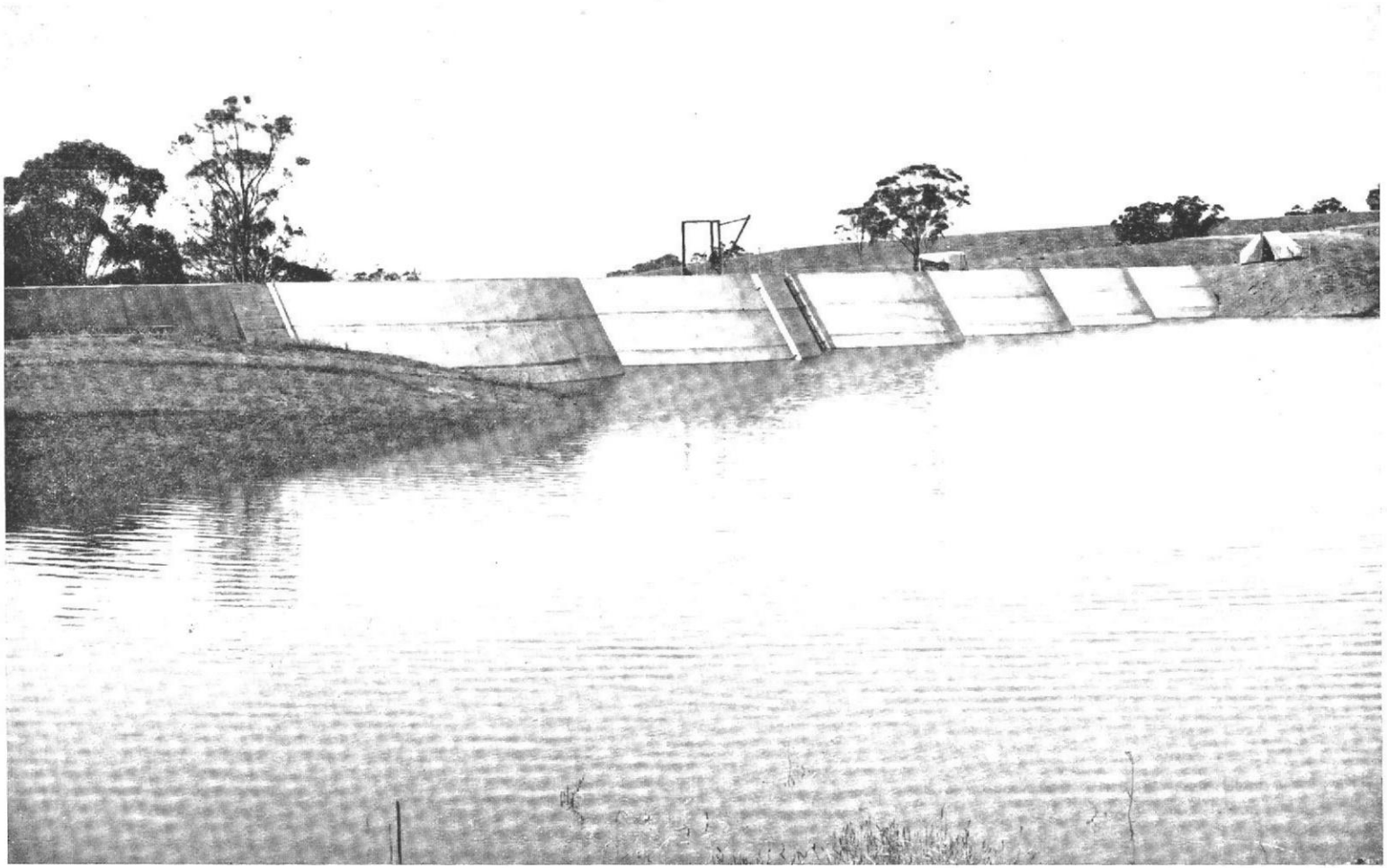
The Smithfield-Fairfield reticulation is now linked up with the general metropolitan reticulation, and has ceased to operate as a separate system.

Camden Water Supply

The Camden Water Supply Works were completed and officially opened in November, 1899, rating commencing from 1st January, 1900. The original installation consisted of a concrete tank with a capacity of 100,000 gallons, built alongside the Upper Canal at Kenny Hill, with which it was connected by a 15-inch pipe. A drop bar weir across the Canal maintained a reserve of water should the Canal be shut off at any time. From the tank an 8-inch steel pipe was laid via Narellan, reducing to 6-inch at the Nepean River, and about $6\frac{1}{4}$ miles of 4-inch reticulation were laid throughout the township. In 1910, the 8-inch steel main, which had been developing defects and giving trouble, was replaced by an 8-inch wood stave pipe. In 1912, the reticulation was extended by the laying of 3,520 yards of 4-inch mains, and the balance of the steel trunk main, viz. the 6-inch portion crossing the Nepean River Bridge, was replaced by a 10-inch cast iron pipe. In 1924, owing to increased



MT. GOLAH ELEVATED STEEL TANK.



INGLEBURN DAM.

summer demand, it was necessary to instal on this main a boosting plant, consisting of a 4-inch Kelly and Lewis 2 stage centrifugal pump direct coupled to a 7½ B.H.P. vertical oil engine. By 1926, the original reservoir, with its level practically that of the canal, had become incapable of giving an adequate supply to the town by gravitation. A new reinforced concrete circular reservoir of 510,000 gallons capacity, with T.W.L. at 550 feet above sea level, was accordingly built on high ground purchased at Kenny Hill near the canal. A pumping plant was installed at the canal consisting of a 55 B.H.P. Blackstone crude oil engine driving a 5-inch 2-stage Kelly and Lewis pump, and this raised water from the canal through an 8-inch cast iron rising main to the reservoir. A 10-inch wood stave main was also laid from the reservoir to the town reticulation replacing the 8-inch wood stave main laid in 1910, which was taken up some few years later.

In 1935 an additional 6-inch 4-stage Kelly and Lewis centrifugal pump belt driven from a 75 H.P. Darcy Paxman vertical oil engine was installed to augment the supply.

Ingleburn-Minto Water Supply

In 1915 the Board approved of a water supply scheme from the Upper Canal for Ingleburn. A guarantee was entered into by local residents covering the deficiency in revenue for a maximum period of 10 years, and the scheme was completed in 1917. The supply was taken direct from the canal at a point as adjacent to the town as possible, the water being conveyed through a 12-inch wood stave pipe laid along easements through private property and across St. Andrews Road and by way of the Hume Highway to Ingleburn and Glenfield. About 11½ miles of reticulation mains were laid in the original scheme. In 1933, a 12-inch cast iron cement lined main was laid along the Hume Highway between the Cross Roads and Denham Court Road to enable the higher levels of Liverpool to obtain an improved supply from the Ingleburn System. In 1934, there was completed, adjacent to the Upper Canal where the trunk main to Ingleburn takes off, a multiple-arch reinforced concrete dam, being the first dam of this type constructed in connection with the Sydney water supply system. It has a capacity of about 9¼ million gallons. The purpose of this work was to provide reserve storage when the canal is laid off for maintenance. At the same time, the extension of the water supply from the Ingleburn take-off to Minto was carried out, and, by means of a branch connection, a supply was given to Campbelltown and Camden for use when the canal is laid off. The extension to Minto and Campbelltown, which was completed in 1935, involved the enlargement of the outlet from Ingleburn Dam from 12-inch to 15-inch (3,100 yards), the provision of a 12-inch trunk main to Minto offtake (2,830 yards), the extension of the 12-inch trunk

main to connect with Campbelltown reticulation (3,872 yards), and the provision of an 8-inch trunk main along the Hume Highway to connect with 8-inch Kenny Hill-Campbelltown main (2,200 yards). About three miles of 8-inch to 4-inch mains were laid to supply Minto.

Service Reservoirs

The service reservoirs supplying the foregoing country centres, exclusive of the two Liverpool and two Smithfield works already listed in Chapter XI, are:—

Year erected	Name	Type	Capacity in gallons	T.W.L. above Sea Level Ft.	Depth
1899 ..	Camden†	Concrete	100,000	370·94	16′
1902 ..	Campbell-town	Concrete	500,000	380·63	16′
1914 ..	Campbell-town H. Level	Cast Iron	22,800	490	5′
1926 ..	Kenny Hill	Reinforced Concrete	510,000	550	18′ 6″
1934 ..	Ingleburn	Multiple Arch Concrete Dam	9,250,000	348	26′
1938 ..	Raby	Reinforced Concrete	575,000	467	25′
1938 ..	Sth. Dural	Steel	1,078,000	732	22′
1938 ..	Marayong	Concrete	2,000,000	314	25′

† Superseded in 1936 by Kenny Hill.

Blacktown-St. Mary's-Riverstone Water Supply

The broad basis upon which extensions of existing reticulation have from time to time been proceeded with has been described in Chapter II. This has been applied, so far as water extensions are concerned, mostly to what may be described as "minor extensions," i.e. relatively short lengths of pipe or works not greatly exceeding, as a general rule, £1,000 in cost. But in one notable instance, viz. the Blacktown-St. Mary's-Riverstone scheme, it has applied to a comprehensive district project.

The genesis of the Blacktown water supply dates back to 1914, when a 6-inch main was laid from Holroyd to Blacktown railway station,

primarily for the use of the railway department. It was not long before the Board, following application by poultry farmers, orchardists, and others, laid reticulation mains in certain portions of Blacktown to the full extent that the capacity of the available supply would permit. Any further extension could then only be carried out by a comprehensive district scheme and one was proposed embracing St. Mary's and Riverstone. The last was within the Windsor Municipality, and therefore outside the Board's "area of operations," as defined in the schedule of the Act of 1924. To permit of its inclusion, action was taken by the Department of Local Government to transfer it to Blacktown Shire, the transfer being gazetted on 4th November, 1927.

The original scheme provided for the supply to take off at the Upper Canal near Calmsley Hill. Later, however, a cheaper alternative was formulated, which served the double purpose of supplying Blacktown, Riverstone and St. Mary's, and augmenting the supply to contiguous districts. Since this scheme was constructed the increased demand in this and adjacent areas has necessitated augmentation of pumping plant and reservoir capacity and the system now consists of a pumping station containing two 150 H.P. and one 100 H.P. units (one of which is a standby), which draw water from Prospect Reservoir through two suction mains, 15-inch and 18-inch diameter respectively. These pumps which are electrically driven and automatically controlled deliver water through an 18-inch rising main to Prospect Elevated Reservoir of 50,000 gallons capacity with top water level 450 feet above sea level and through an 18-inch rising main to Prospect Hill (Surface) Reservoir, with a capacity of 3 million gallons and top water level 377 feet above sea level. From the elevated reservoir the major portion of Blacktown Shire and the whole of St. Mary's Municipality is supplied by a main laid chiefly along the Great Western Highway (5,000 feet of 18-inch cast iron pipe and 20,000 feet of 15-inch wood stave pipe to Rooty Hill Road, and from thence to Kingswood, 14,300 feet of 10-inch and 27,750 feet of 6-inch cast iron pipe), and by a branch trunk main to Quakers Hill and Riverstone which is 12-inch diameter woodstave and cast iron, length 36,500 feet, and 10-inch cast iron length 19,000 feet.

An 18-inch diameter cast iron branch from the above main at Quakers Hill will serve the recently completed Marayong balance reservoir of 2 million gallons capacity, with top water level 314 feet above sea level, to provide storage for a large portion of the area in case of emergency or at times of peak demand. A small portion of Blacktown Shire is included in the Holroyd zone supplied from the reservoir at Prospect Hill. The function of this reservoir is to enable economy in pumping costs to be effected by utilising it to supply certain areas which do not call for the high pressure derived from the elevated reservoir. In addition it provides a better pressure for certain areas formerly fed

from Holroyd Reservoirs, and now supplies water to those reservoirs thus superseding the system of pumping from Pipe Head.

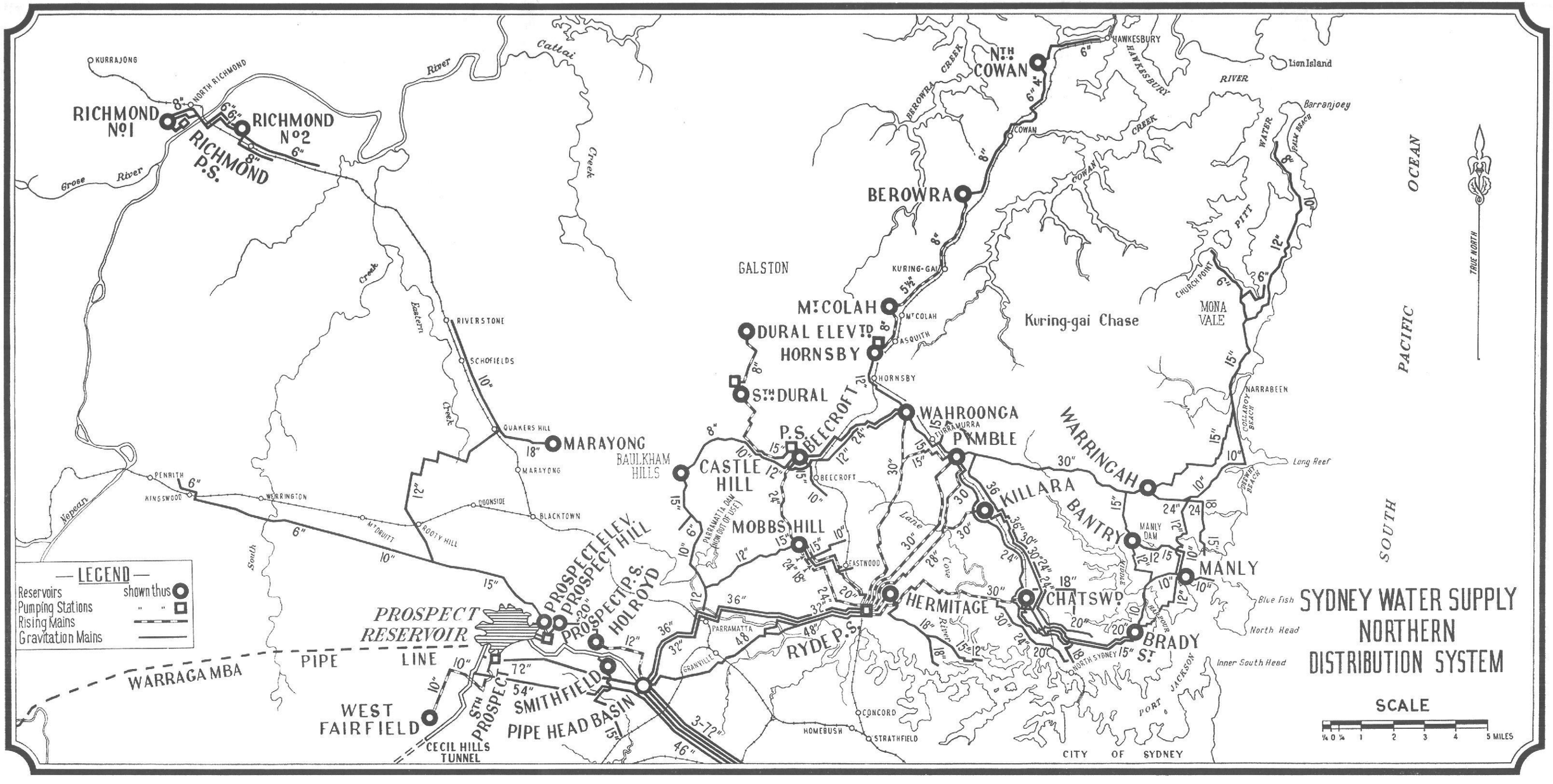
The scheme was commenced in 1929, but shortly afterwards, the onset of the economic depression necessitated the closing down of operations. The work was carried forward in stages as limited loan funds, supplemented by a grant from Unemployment Relief Funds, would permit during 1931 and 1932, until in June, 1933, available loan funds added to by £44,000 advanced from Unemployment Relief Funds, enabled the Board to concentrate on completion of the scheme as then planned, which was effected in 1934. Inclusive of later extensions of reticulation mains, the cost to 30th June, 1938, is £176,750. An agreement which was executed by the councils concerned (Blacktown and St. Mary's) in March, 1934, provided for the making good by those bodies of any deficiencies between 5 per cent of the cost and the revenue yielded the Board from the metropolitan water rate and meter charges levied against the properties served. The liability in this respect was, however, taken over by the Government in common with all other similar council liabilities from 1st July, 1936.

In December, 1937, on the completion of the surface reservoir at Prospect Hill, a re-zoning of the supply to Blacktown-St. Mary's and Holroyd was effected.

The Blacktown-St. Mary's-Riverstone scheme was the first of a series of modern attempts to extend in any large way the reticulation to rural areas on the fringe of the metropolitan system, and was followed in succession by the Asquith-Mt. Colah water supply (placed in commission in June, 1935), the Menangle-North Menangle water supply (placed in commission in October, 1936), the West Fairfield supply (Bossley Park-Horsley Park, Edensor Park); the Raby, Austral and Hoxton Park* and the Hills District* water supplies, and the extension of the Asquith-Mt. Colah scheme to Brooklyn* (the last four at present under construction). Of these, those marked * have been carried out with the assistance of the Government, the Board meeting the cost of materials, supervision and skilled labour and the Government the cost of unskilled labour, the Government also guaranteeing any deficiency between 5 per cent on the expenditure from the Board's funds plus the cost of operating expenses and the actual revenue received.

Asquith-Mt. Colah-Brooklyn Water Supply

The Asquith-Mt. Colah-Brooklyn water supply serves the districts along the Northern railway line between Hornsby and the Hawkesbury River. It consists of a pumping station, established in the grounds of the Hornsby Reservoir (height above sea level 672·5 feet) from which water is pumped through a 6-inch rising main to an elevated steel tank of 35,000 gallons capacity, erected at Mt. Colah, at a height above sea level of 750 feet. For the original scheme to Mt. Colah, two 12½ B.H.P. electrically driven centrifugal pumps were installed. Under the extended


SYDNEY WATER SUPPLY
NORTHERN
DISTRIBUTION SYSTEM
SCALE
¼ 0 ¼ 1 2 3 4 5 MILES
— LEGEND —
Reservoirs shown thus
Pumping Stations
Rising Mains
Gravitation Mains
RICHMOND No 1
RICHMOND No 2
RICHMOND P.S.
KURRAJONG
NORTH RICHMOND
Grose River
Cattai Creek
RIVERSTONE
SCHOFIELDS
QUAKERS HILL
MARAYONG
BLACKTOWN
PENRITH
KINGSWOOD
WORRINGTON
Nepean River
South Creek
Eastern Creek
M'DRUITT
BOOTY HILL
ROONSIDE
PROSPECT RESERVOIR
PROSPECT ELEV.
PROSPECT HILL
PROSPECT P.S.
HOLROYD
PROSPECT PIPE LINE
WARRAGAMBA
WEST FAIRFIELD
5th PROSPECT
CECIL HILLS TUNNEL
SMITHFIELD
PIPE HEAD BASIN
PARRAMATTA
GRANVILLE
RYDE P.S.
CONCORD
HOMEBUSH
STRATHFIELD
CITY OF SYDNEY
PORT JACKSON
GALSTON
BAULKHAM HILLS
CASTLE HILL
PARRAMATTA DAM (NOW OUT OF USE)
MOBBS HILL
EASTWOOD
BEECROFT
P.S. BEECROFT
DURAL ELEVTD
HORNSBY
ASQUITH
M'COLAH
KURING-GAI
STH DURAL
BEROWRA
BEROWRA CREEK
NTH COWAN
COWAN
HAWKESBURY
HAWKESBURY RIVER
Lion Island
Barranjoey
PITT WATER
Palm Beach
Kuring-gai Chase
MONA VALE
CHURCH POINT
NARRABEEN
COLLAROY BEACH
NEWPORT BEACH
Long Reef
PACIFIC OCEAN
SOUTH
WAHROONGA
PYMBLE
WARRINGAH
KILLARA
BANTRY
MANLY DAM
MANLY
HERMITAGE
CHATSWD
BRADY ST
NORTH SYDNEY
Blue fish
North Head
Inner South Head
TRUE NORTH

scheme to Brooklyn, these will be replaced by two 35 B.H.P. units, which, in addition to supplying Mt. Colah service reservoir, will deliver water through an 8-inch rising main to be laid from the termination of the existing 5½-inch main at Mt. Ku-ring-gai, to a new elevated reservoir of 150,000 gallons capacity to be constructed at Berowra (height above sea level, 810 feet). The Brooklyn area will be supplied from Berowra Reservoir via another new reservoir to be erected at North Cowan of 500,000 gallons capacity (height above sea level, 340 feet). The length of mains included in this extension is over 15 miles, the pipes being from 4-inches to 8-inches in diameter. The cost of the original extension to Mt. Colah was about £15,000. The estimated cost of the further extension to Brooklyn is £52,790.

Menangle and North Menangle Water Supply

The Menangle and North Menangle scheme, which was carried out in 1936 at a cost of £7,580, draws its supply from the Campbelltown Reservoir outlet main whence a 6-inch cast iron cement lined trunk main is laid, partly in tunnel, under the Upper Canal for a distance of a little over 1¼ miles to North Menangle. The reticulation consists of about 2¼ miles of 3½-inch fibrolite pipes.

West Fairfield Water Supply

The West Fairfield scheme (estimated cost £59,286) has been designed to supply Horsley Park and areas at Bossley Park, Edensor Park and Bonnyrigg adjacent to but higher than the zones supplied from Liverpool Dam. Water will be pumped from Prospect Reservoir or the Upper 72-inch main at South Prospect Pumping Station (to be constructed) and will be delivered through a 10-inch main into the reticulation or into a reservoir which is being constructed on high land west of the Upper Canal. This reservoir will have a capacity of 600,000 gallons and a top water level 515 feet above sea level.

Raby, Austral-Hoxton Park Water Supply

The Raby, Austral-Hoxton Park water supply scheme (estimated cost £49,094) to serve rural areas situated partly in the Nepean Shire, and partly in Campbelltown Municipality, comprises the erection of a pumping station at Ingleburn Dam, in which there will be installed two 12½ B.H.P. electrically driven centrifugal pumps to be transferred from Hornsby reservoir. A reservoir has been erected at Denham Court Road, Raby, near the Upper Canal, of 575,000 gallons capacity, which the pumps referred to will supply. The rising and outlet mains are of 10-inches and 8-inches diameter, and nearly 7 miles in length. The reticulation consists of about 18 miles of 6-inch and 4-inch mains. Fibrolite pipes have been used where pressures permit, except for the rising main.

Hills District Water Supply

The Hills District scheme (estimated cost £95,725) provides for a major extension of water facilities from Beecroft to serve Glenhaven, Dural, Kenthurst, Galston, Arcadia and Glenorie. A pumping station with two electric units of approximately 20 B.H.P. is located at Beecroft Reservoir, from which water will be pumped through a 15-inch rising and gravitation main to a surface reservoir (capacity 1,000,000 gallons, height above sea level 732 feet) at South Dural. For this purpose the steel reservoir formerly at Ryde Hill has been transferred. A second pumping station with two electric units of approximately 10 B.H.P. will be located beside the South Dural Reservoir, and water will be pumped through 8-inch and 10-inch mains to an elevated reservoir in the Dural-Galston road, which will have a capacity of 300,000 gallons. The outlet mains from the two reservoirs will be connected to the rising mains.

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Ingleburn Dam—"Commonwealth Engineer," 1st May, 1934.

CHAPTER XIII

INDEPENDENT WATER SUPPLY SCHEMES ABSORBED IN THE GENERAL METROPOLITAN SYSTEM

Two previously independent schemes have been absorbed in the general metropolitan system as it has developed. These are the Manly and Parramatta water supplies. The former was taken over by the Board on 1st January, 1902, under Act 5 of 1902, and the latter on 1st January, 1917, under Act No. 13 of 1916.

The original Manly water supply consisting of a dam, pumping station, rising main, service reservoir and reticulation was constructed by the Government for the local Council under a special Act and was operated by the Council for a period of ten years, prior to the Board assuming control. It was taken over by the Board at its original cost (£37,820) less the amount (£454) that had been paid off by the Council. Its catchment area or source of supply is the basin of Curl Curl Creek, extending from a point on that creek about 2 miles north-west of Manly, where a dam was constructed, to French's Forest, being bounded on the west by the ridge between Middle Harbour and Curl Curl Creek and on the north-east by the ridge between the creek and Brookvale. The area of the catchment basin is 1,288 acres. Of this, 124 acres is alienated land; 211 acres was later resumed or purchased by the Board (together with 43 acres of land adjoining but outside the catchment boundary), and the remainder is Crown land dedicated for water supply under the Board's trusteeship.

The dam (concrete) originally had an impounding capacity of 68,216,000 gallons and was 280 feet long, 37 feet high, with a maximum width at base of 38 feet, a crest width of 3 feet, and top water level at 91.25 feet above sea level. In 1909, an enlarged by-wash was excavated on the eastern side, and the old by-wash built up. This enabled the top level of the reservoir to be raised, increasing its storage capacity to 84 million gallons and the top water level to 93 feet above sea level. In 1914 it was again raised to 94·75 feet with increased capacity 90·5 million gallons, and in 1922 to 115 feet with an increased storage capacity of 428 million gallons. A filtration plant was installed in 1920, consisting of settling and coagulating basin, filter beds (gravel and sand), inspection

chambers and clear water basin. Oil engines and gear were used for actuating the lime mixing and dosing apparatus, and an air compressor and receiver for agitating the filter beds during washing. The filter beds were reconstructed in conformity with the Candy system in 1928, specially graded gravel obtained from New Zealand being used.

The original pumping plant consisted of two horizontal compound Fielding and Platt duplex pumps having a capacity of 1 million gallons in 17 hours each, for which steam was supplied by two multitubular boilers burning wood fuel. In 1918, the latter were replaced by two Babcock and Wilcox boilers transferred from Potts Hill. In 1921, one of the two original pumping units being worn out, it was removed and an 18-inch Worthington plunger pump from Chatswood put in its place. Between 1923 and 1926, three new Worthington plunger pumping units (one 16-inch and two 12-inch) were installed, together with a third Babcock and Wilcox boiler, also transferred from Chatswood.

The original service reservoir, situate on Red Hill overlooking Manly has a capacity of nearly 1 million gallons and its top water level is 228 feet above sea level. In 1916, a small elevated cast iron tank (of 13,238 gallons capacity) was placed alongside it, with T.W.L. at 270·83 feet above sea level, to improve the supply to the higher levels, and an electrically operated pump, automatically controlled, was installed to keep it filled. This was rendered obsolete in May 1924 when a circular reinforced concrete reservoir, capacity 1½ million gallons, top water level 435 feet, supplied direct from Manly pumping station, was completed on the heights above Bantry Bay.

The original rising main from the pumping station to the service reservoir on Red Hill consisted of a 10-inch cast iron pipe. It was replaced in 1924 by a 15-inch main, the old main being taken up and the pipes fettled and used with new 8-inch cast iron pipes in the extension of the supply from Brookvale to Narrabeen. Concurrently with the construction of the reservoir at Bantry Bay, a 12-inch rising main was laid to it from the pumping station and a 12-inch-10-inch trunk main laid from the reservoir to Balgowlah and Seaforth to feed the local reticulation.

In 1906, i.e. prior to the first enlargement of the dam, it had been found necessary to supplement the local supply by connecting it with the metropolitan system. For this purpose a 10-inch main was laid from the reservoir at Brady Street, Mosman, to the Spit, crossing Middle Harbour with ball and socket pipes and thence along the Manly road to Condamine Street, where it connected with the existing main leading to the Red Hill service reservoir. In 1920, this main was supplemented by a 12-inch main following a different route, the Middle Harbour crossing which was near Clontarf being in 10-inch ball and socket pipes as

before. The supply from the Mosman reservoir was heavily drawn upon in the intervening years until 1924, when the enlargement of the Manly storage dam, the additions to the pumping plant and the erection of the Bantry Bay Reservoir enabled the local system to take over for the time being the whole of the supply to Manly and Warringah Shire to the extent to which the latter was then supplied. The reticulation was extended to the district of Mona Vale during 1926.

By 1928, it was recognised that the Manly scheme had reached the limit of its capacity, and that future expansion of the reticulation systems in Manly and Warringah would have to be met from the metropolitan system. As the expansion would be mainly along the coast from Brookvale to Barrenjoey, it was considered that the proper course was to bring the metropolitan water supply from Pymble with improved pressure instead of from Mosman Reservoir. In 1929, therefore, a trunk main was laid from Pymble Reservoir to a woodstave break pressure tank of 50,000 gallons capacity, situated on Rocky Hill above Brookvale. The main is $8\frac{1}{2}$ miles in length, of which over $5\frac{1}{2}$ miles consists of 30-inch machine banded woodstave pipes, mild steel pipes being used where the static head exceeds 350 feet. For the greater part of the distance the pipes are carried on concrete saddles on the surface. The Middle Harbour crossing is on an 80-ft. steel truss bridge with approach spans. A 24-inch main was laid from the break pressure tank to connect with the Warringah Shire reticulation at Brookvale. In 1933, a 15-inch cement lined steel main was laid to connect the Bantry service reservoir with the main from Pymble. This obviated pumping from Manly dam to this reservoir. In the same year, work was commenced on a 10 million gallon reinforced concrete service reservoir on Rocky Hill at the termination of the 30-inch woodstave main. This work, which was designed to function as a reserve supply to Manly-Warringah districts, and to meet the rapid expansion of the reticulation system, was completed early in 1936. A 15-inch trunk main was laid simultaneously from the reservoir to Mona Vale to feed the recently extended reticulation in Mona Vale, Newport and Palm Beach districts, and a 24-18-15 inch main from the reservoir outlet main near Brookvale into North Manly, to improve the supply to this locality.

With the completion of these works, the necessity for continuing the original source of supply to Manly from the Curl Curl catchment ceased, and the pumping plant, etc., at the dam was dismantled and disposed of. All that now remains to be done is to decide on the future use of the catchment area lands, which matter is at present engaging the attention of the Department of Lands, the Board and the local council.

The Parramatta Water Supply Scheme, which was similar to, although smaller than the Manly scheme, was taken over by the Board at a valuation of £24,663 7s. 10d., embracing a dam at Hunt's Creek, filter beds, settling tanks, pumping plant and machinery and mains. Shortly after taking over, the town supply was connected to the general metropolitan system, the high lands to the north being supplied from Mobbs Hill and the western heights from Holroyd Reservoir. Development of the supply to Parramatta and adjacent districts therefore became part of the general expansion of the metropolitan system and the scheme ceased to exist as a separate unit. The Hunt's Creek Reserve of 117 acres with the dam is now a public recreation area.

CHAPTER XIV

WOLLONGONG AND SOUTH COAST WATER SUPPLY

The South Coast, which, for purposes of water supply as dealt with in this book, consists of a narrow strip of land extending from Stanwell Park on the north to Dapto on the south, bounded on the east by the Pacific Ocean and the west by a high ridge which constitutes the eastern boundary of the Upper Nepean and Woronora catchment areas, is approximately 23 miles long and varies in width between ¾ and 7 miles. It is dotted throughout its length with towns and villages, devoted to mining, industrial or holiday purposes. The largest of these is Wollongong, situated 52 miles from Sydney, with Port Kembla adjacent, the latter showing signs of becoming the Newcastle of the south, and destined to be one of the great industrial centres of the State. It is obvious that in such a strip of country no substantial catchment area is available, and for water supply purposes it must draw its resources from beyond the ridge which separates it from the hinterland. The nearest of the Upper Nepean tributaries, viz., the Cordeaux River, is the one that has been called upon for this purpose. In the early stages, when development was small and demand corresponding, the upper reaches of the Cordeaux could be dammed at sufficient height to pass the stored water by gravity over the ridge (1,045 feet above sea level) to the coast, but as demand increased and the need for storage likewise, this could only be obtained by dams at lower levels. Then it was necessary to lift the water by pumping to the top of the ridge from which it would readily gravitate. The first dam (completed in 1903) was able to pass water over the ridge by gravity; the second, constructed in 1915, 1¼ miles downstream of the first, had to have its water lifted by pump to enable it to discharge to the coast. Later a dam, which aimed to develop the full resources of the Cordeaux River for the metropolitan supply and was 6¼ miles lower than the first, was constructed. This was drawn on for additional local supply but required to have every gallon of its water sent to the south coast lifted over the ridge by a separate pumping station. The height of the ridge above the coast has meant also that the pressure in the trunk mains is very high—too high to be admitted to reticulation mains without breaking down. Consequently another feature of the south coast system is its numerous service reservoirs (17), situated at high points outside each town or village, whose functions are to act both as service reser-

voirs and break pressure tanks. The most striking feature of recent years has been the establishment of the steel industry at Port Kembla. This has meant intense industrial demand at that centre and largely increased domestic demand at Wollongong, and great efforts have had to be made to keep the water supply up to these developments.

The genesis of the South Coast scheme took place in 1902-1903, when a water supply scheme for the town and district of Wollongong was constructed by the Public Works Department. The works then built consisted of a storage reservoir (now known as the Upper Cordeaux No. 1 Dam), a 10-inch steel trunk main, which followed the course of the Cordeaux River and Kembla Creek to O'Brien's Gap on the top of the south coast range above Kembla Heights, a 6-inch steel main from this point to a service reservoir in Wollongong, together with certain reticulation, the whole costing £191,200. This work, on completion, was handed over by the Minister for Public Works to the Board on 19th January, 1903, for control and management, although at that time the Board had no legal jurisdiction to operate outside the County of Cumberland, consequently for some years water was only supplied to those owners who would agree to take it. In 1916, an Act (No. 13) empowering the Governor by proclamation in the Gazette to extend the Board's control to areas outside the County of Cumberland was passed, and following this the Wollongong and South Coast Water Supply works were vested in the Board. A later Act (No. 50 of 1924) included in the Board's area of operations the whole of the municipalities or shires of Wollongong, Central Illawarra, North Illawarra and Bulli.

From a constructional point of view, the South Coast water supply scheme has developed in definite phases. The first was, of course, the original scheme supplying Wollongong only, followed in 1909 by extension to Port Kembla and Unanderra. The next was the comprehensive extension in 1915 to the towns to the north of Wollongong, viz., Figtree, Mount Kembla, Kembla Heights, Mount Keira, Keiraville, Balgownie, Corrimal, Bellambi, Russell Vale, Woonona, Bulli, Thirroul, Austinmer, Coledale, Scarborough and Clifton. Supplementary to this were the extensions to Dapto (1920) and to Mount Drummond (now Mangerton), Turrawanna, Reidtown, Fern Hill and Fairy Meadow in 1922. Since that date, it has been a matter of expansion within all these areas. The following figures denote the growth of the system:—

Year	Population Supplied	Water Supplied for the Year: in million gallons
1903	3,700	46.25
1916	15,055	236.25
1926	32,540	430.75
1938	41,614	1,233.00

The original, or No. 1 Upper Cordeaux Dam, which has an impounding capacity of 173 million gallons and a lake area of 49 acres, with a top water level of 1107.9 feet above sea level, is built of concrete, and is 540 feet long, 35 feet 9 inches high from crest to outlet pipe and 3 feet 6 inches wide at the crest. Its major portion is an arch, curved to a radius of 200 feet and is 10 feet 6 inches thick at the base. The flanks are of gravity section.

The second, or No. 2 Upper Cordeaux Dam, which was constructed to provide the additional storage required by the second phase of development, is built on similar lines to No. 1, with a storage capacity of 260 million gallons. Its length is 910 feet, top water level 1039.9 feet above sea level, and lake area 58 acres. With it was installed an electrically driven pumping plant to pump the water to the coast or to No. 1 Dam, whence it passed into consumption, the excess pressure at a break pressure tank on Mt. Nebo being utilised to generate with the aid of a Pelton wheel, the required electrical energy to drive the three phase induction motor operating the pump. In 1920, further pumping plant was added. Later, when electrical power became available from the Port Kembla-Avon Dam transmission line, a 150 K.V.A. transformer was installed, and the generating plant at Mt. Nebo was dismantled and sold.

With the increasing demand on the two dams it became necessary in 1921 to provide filters. In that year, eight rapid sand filters of the Patterson type, having a capacity of one million gallons per day, were installed, together with all appurtenances, just below No. 2 Dam.

In 1930, following the completion of the main Cordeaux Dam in connection with the metropolitan supply, it became possible to draw water from this storage also, and in that year a centrifugal pumping plant with a capacity of 2,600 gallons per minute at 105 feet head driven by direct coupled 125 B.H.P., A.C. motor was established on the upper reaches of that dam. Its duty was to pump water from the dam into the main to O'Brien's Gap to supplement the supply from the Upper Cordeaux Dams. The unit was so constructed as to be movable according to the level of the water in the reservoir. To enable this pump to be operated at the same time as that at No. 2 Dam, a second transformer of 100 K.V.A. 33,000-415 volt capacity was added.

During 1938, when it appeared that the water level in the main Cordeaux Dam might reach the limit of suction for this pump if the drought continued, an emergency pumping station, together with a 30-inch diameter pipeline was constructed ¼ miles downstream on the opposite side of the reservoir, in such manner as to enable water to be drawn off to a further depth of 19 feet with provision for a future lowering for 16 feet further. Fortunately, the heavy rain which fell in August rendered the use of this unnecessary.

The original supply main from the dam served until 1915, when, in connection with the extension of the water supply to towns north of Wollongong, a woodstave pipeline 14-inches in diameter was laid from No. 1 Dam to O'Brien's Gap, from which point a high pressure gravitation main of 11-9-6-inches steel pipes carried the supply to various break pressure tanks between Wollongong and Clifton. In 1916, to improve the supply, a 10-inch cast iron main was laid from Mt. Nebo to Wollongong Service Reservoir, and from there to Keira Street, Wollongong. In 1922, a third main (15-inch reinforced concrete) was laid from No. 1 Dam to O'Brien's Gap to supplement supply through the 10-inch steel and the 14-inch woodstave mains, and in 1927 an additional main (8-inch), portion in cast iron and the remainder in steel, was laid from O'Brien's Gap to Mt. Nebo Junction. In 1928, a duplicate trunk line, 8 miles in length, from Mt. Nebo Junction, of 10-inch and 9-inch diameter bitumen coated Mannesman pipes, was laid to improve the supply to the service reservoirs north as far as Thirroul. Half the length was fitted with victualic joints and half with spigot and socket rigid joints. In 1933, a 20-inch welded steel bitumen-lined main was laid from the Princes Highway to Mt. Drummond (now known as Mangerton) and continued in 12-inch pipes to Five Islands Road, Port Kembla, to meet increased industrial consumption. A reservoir was constructed on Berkeley Hill and connected to this main. The 20-inch main was later continued from the Princes Highway to Mt. Nebo and from there to O'Brien's Gap.

In 1935, a 30-inch reinforced concrete main was laid from Cordeaux Dam to O'Brien's Gap, superseding the 14-inch woodstave main and the 15-inch concrete. In July, 1936, a trunk main extension from the end of the existing 10-inch main near Bulli to the Bulli Reservoir branch main was carried out in 10-inch mild steel imported pipes. Work is at present in progress on amplification of Port Kembla supply to meet prospective development there. This involves nearly 5 miles of large size mains varying from 15-inches to 8-inches diameter. The total length of mains in the system is 217 miles.

On the next page is a list of the service reservoirs supplying South Coast towns. The first is the original service reservoir taken over by the Board in 1903. The 1915 group was added when the system was extended to the towns north of Wollongong. The Dapto tank is the cast iron tank formerly at Gore Hill, North Sydney, from which it was transferred and erected on supports on an elevated site near Dapto, when supply was extended to that town. The Berkeley, Thirroul (No. 2) and Mangerton Reservoirs mark the large development that has taken place on the South Coast, particularly at Port Kembla, in more recent years. Operations are

SOUTH COAST WATER SUPPLY DISTRIBUTION SYSTEM

SCARBOROUGH
SCARBOROUGH
C. Horn
WOMBARRA
COLEDALE
COLEDALE & B.P. TANK
Long Pt
AUSTINMER
THIRROUL
THIRROUL
Bulli Pt
BULLI-WOONONA
BULLI
Waniora Pt
Flat Rock
WOONONA
BELLAMBI
Bellambi Pt
CORRIMAL
CORRIMAL
BALGOWNIE
BALGOWNIE
Flagstaff Pt.
MT KEIRA
NTH WOLLONGONG
MT NEBO
WOLLONGONG
MANGERTON
KEMBLA HGTS
KEMBLA
CONISTON
TOM THUMBS LAGOON
UNANDERRA
CRINGILLA
Port Kembla
BERKELEY
KEMBLA CRA.
PT KEMBLA
Red Pt
Gooseberry Id
Hooka Id.
GRIFFENS B.
DAPTO
DAPTO
LAKE ILLAWARRA
WINDANG
Cataract Dam
CATARACT STORAGE RESERVOIR
Cataract R.
Loddon Ck
CORDEAUX STORAGE RESERVOIR
Pumping Stn.
Cordeaux R.
Goondarrin Ck
Upper Cordeaux Pumping Stn.
UPPER CORDEAUX
WOLLONGONG S. pipe
WOLLONGONG STORAGE RESERVOIRS
STORAGE RESERVOIR
River
Dapto Ck
Mullet Ck
Allans Ck
MAGNETIC MERIDIAN
OCEAN
PACIFIC
SOUTH

LEGEND

High pressure Mains shewn thus
Gravitation Mains " "
Rising Mains " "

SCALE

20 0 20 40 60 80 100 120 140 CHAINS
¼ 0 ¼ ½ ¾ 1 1¼ 1½ 1¾ MILES

in progress on a service reservoir at Upper Cordeaux to provide storage to regulate pumping to the South Coast towns.

Service Reservoirs Supplying South Coast Towns

Name	Year Constructed	Construction	Capacity in Gallons	Top Water Level Height above sea level, feet
Wollongong	1903	Concrete	400,000	247.31
Port Kembla	1909	,,	501,200	148.44
Mt. Nebo	1915	Steel	50,000	472.92
Mt. Keira		Concrete	100,000	472.75
Balgownie		,,	100,000	254
Corrimal		,,	254,000	253.01
Bulli-Woonona ..		,,	355,000	314.61
Thirroul No. 1 ..		,,	150,000	394.23
Coledale		,,	150,000	593.85
Coledale		Steel	50,000	228
Clifton-Scarborough		Concrete	150,000	470.54
Kembla		Steel	50,000	603.76
Kembla Heights* ..		Steel	206,000	947.94
Dapto	1920	Cast Iron	53,000	216
Berkeley	1933	Concrete	1,000,000	423.83
Thirroul No. 2 ..	1937	,,	500,000	394.23
Mangerton	1937	,,	1,274,000	340

* Reduced in 1937 to 66,800 gallons T.W.L. 902.15.

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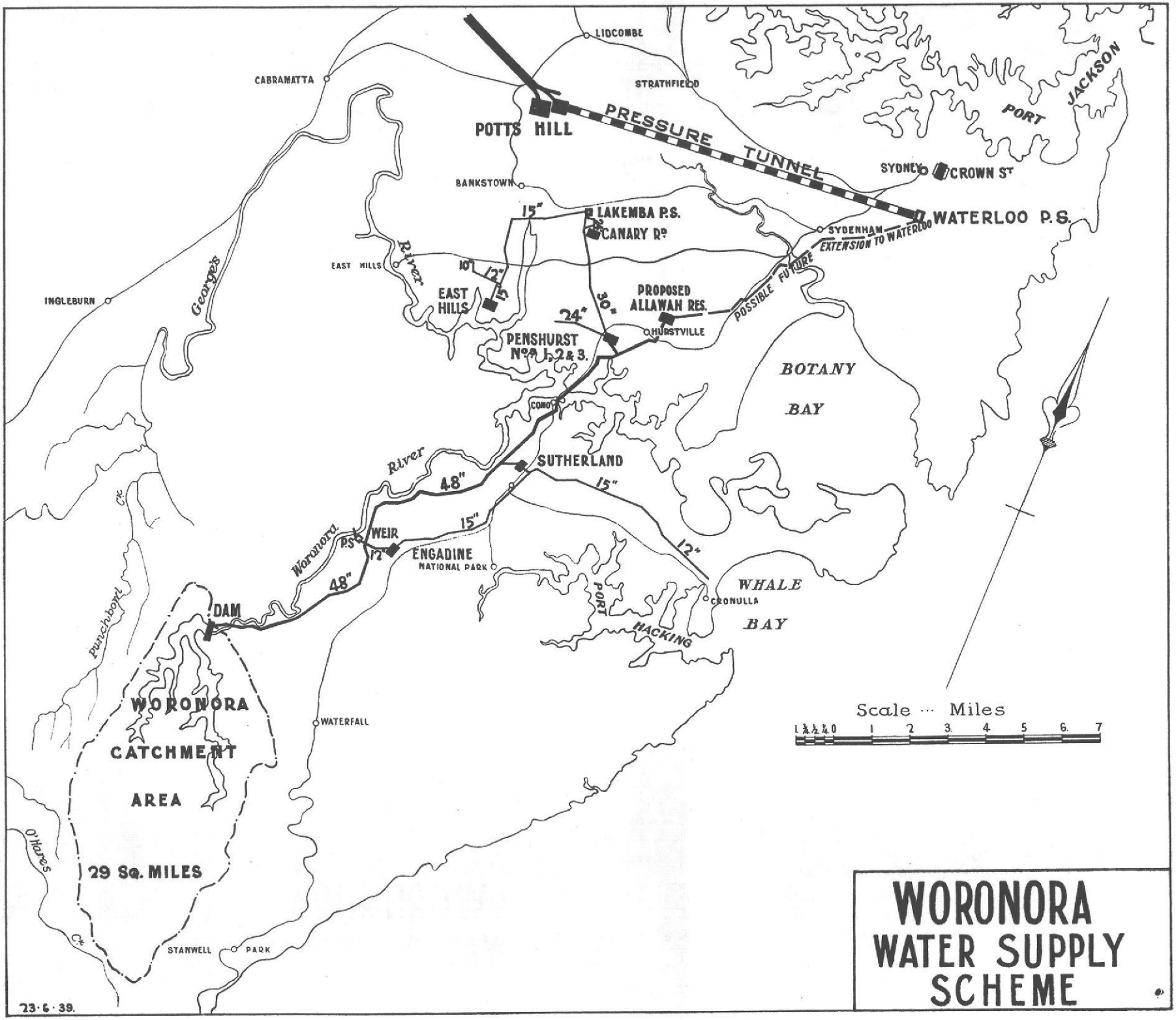
CHAPTER XV

WORONORA AND WARRAGAMBA DEVELOPMENTAL WORKS

In Chapter IX it has been shown how the Upper Nepean catchment area has been steadily developed to the limit of its present economic capacity. As this has taken place, consideration has had to be given to the next source of supply. The available alternatives in any proximity to the metropolitan area are shown on the map at frontispiece. They consist of—

River	Direct Distance in Miles		Bed R.L. at site of storage	Catchment Area in sq. miles
	From Prospect	From Sydney		
Woronora River	19	22	352′	29
O'Hare's Creek	22½	28	544′	29
Colo River	28	42	25′	1,680
Grose River	17	35	—	250
Erskine River	16	36	—	89
Shoalhaven River—				
(a) at Warri Bridge ..	122	131	1,714′	572
(b) above Meangora ..	102	110	1,455′	1,200
Warragamba River	15½	35½	35′	3,383

Of these, the first two, Woronora and O'Hare's Creek, which are tributaries of George's River, have the advantage of proximity, of uninhabited catchments, and of providing supplies entirely independent of the Upper Nepean Head Works. In the event, therefore, of any damage to the last interrupting supply over a prolonged period, Woronora and O'Hare's Creek could give service to a substantial portion of the southern part of the Metropolis. Warragamba, the last on the list, has a catchment area far in excess of any of the others, and could be counted upon to supply a correspondingly larger quantity of water. It debouches into the Nepean River at Wallacia, and immediately above this junction, passes through a deep sandstone gorge 400 feet high. Suitable escape way for surplus waters can be readily provided by a cut into an adjoining gully known as Megarrity's Creek. The situation is therefore suitably conformed to the construction of a high masonry dam. Its catchment area, however, is inhabited (it includes the towns of Lithgow and Goulburn) and its waters need treatment before use. It is not surprising that attention has largely been focussed on these areas as the


LIDCOMBE
CABRAMATTA
STRATHFIELD
PORT JACKSON
POTTS HILL
PRESSURE TUNNEL
SYDNEY
CROWN ST
BANKSTOWN
15"
LAKEMBA P.S.
CANARY Rd
WATERLOO P.S.
SYDENHAM
EXTENSION TO WATERLOO
POSSIBLE FUTURE
EAST HILLS
River
10"
12"
15"
EAST HILLS
INGLEBURN
George's
30"
PROPOSED ALLAWAH RES.
24"
HURSTVILLE
PENSHURST
No's 1, 2 & 3.
BOTANY BAY
COMO
SUTHERLAND
River
48"
15"
Woronora
P.S.
WEIR
12"
15"
12"
ENGADINE
NATIONAL PARK
48"
WHALE BAY
CRONULLA
PORT HACKING
DAM
Punchbowl Ck
WORONORA CATCHMENT AREA
29 Sq. MILES
WATERFALL
O'Hares Ck
STANWELL PARK
Scale ··· Miles
1 ½ ½ 0 1 2 3 4 5 6 7
WORONORA
WATER SUPPLY
SCHEME
23·6·39.

next to be considered after the Upper Nepean. The use of the Warragamba River was, it will be recollected, one of the schemes considered by the Commission of 1867, which ultimately recommended the Upper Nepean Scheme, and was only rejected on the score of the difficulty, in the then stage of knowledge of dam construction, of building a dam capable of withstanding the floods likely to occur in that river.

Following its reconstitution in 1925, the Board decided in February, 1926, to convene a Committee to continue the work of the Special Board referred to in Chapter X. This consisted of:—

Mr. T. B. Cooper (Chairman), President, Metropolitan Water Sewerage and Drainage Board.

Mr. H. H. Dare, M.E., M.Inst.C.E., Commissioner for Irrigation.

Mr. E. M. de Burgh, M. Inst.C.E., Chief Engineer, Water Supply and Sewerage, Department of Public Works.

Mr. T. W. Keele, M.Inst.C.E., Commissioner, Sydney Harbour Trust, and ex-President of the M.W.S. & D. Board.

Mr. J. G. S. Purvis, M.Inst.C.E., Chief Engineer, Metropolitan Water Sewerage and Drainage Board.

This Committee, which issued only one formal report, recommended that the construction of a dam, to be 327-ft. high (foundation to crest), across the Warragamba River, should be undertaken following the completion of the Nepean Dam, and considered that its construction should be advanced to a sufficient extent to permit of its contributing additional water to the metropolitan area in 1938.

At that time also, consideration was being given to the development of the Woronora River, but primarily as a source of supply for the Sutherland-Cronulla peninsula. This led to the decision to construct a dam 60-ft. high across it, but to so construct the foundations that the dam could at a later stage be raised to 120-ft. to afford a supplementary supply to Penshurst Reservoirs via a proposed 15-inch woodstave main for distribution to the Illawarra Suburbs. While this work was under way, investigations of runoff and safe draught were continued, which led the Chief Engineer (Mr G. Haskins, M.Inst.C.E.) to recommend in November, 1928, that the Woronora Dam should be increased in height to 200-ft., giving an estimated capacity of 15,000 million gallons with a safe draught of 20 m.d.g., and connected with Penshurst Reservoirs via a 33-inch dia. steel main (subsequently altered to 42-inches), and that these works should be proceeded with forthwith; correspondingly the construction of Warragamba Dam should be deferred for four years. The Board agreed to this course and action was taken accordingly.

On 14th July, 1932, Mr Haskins submitted a further report recommending that the construction of Woronora Dam should be followed by that of a dam on O'Hare's Creek. He estimated from the then available

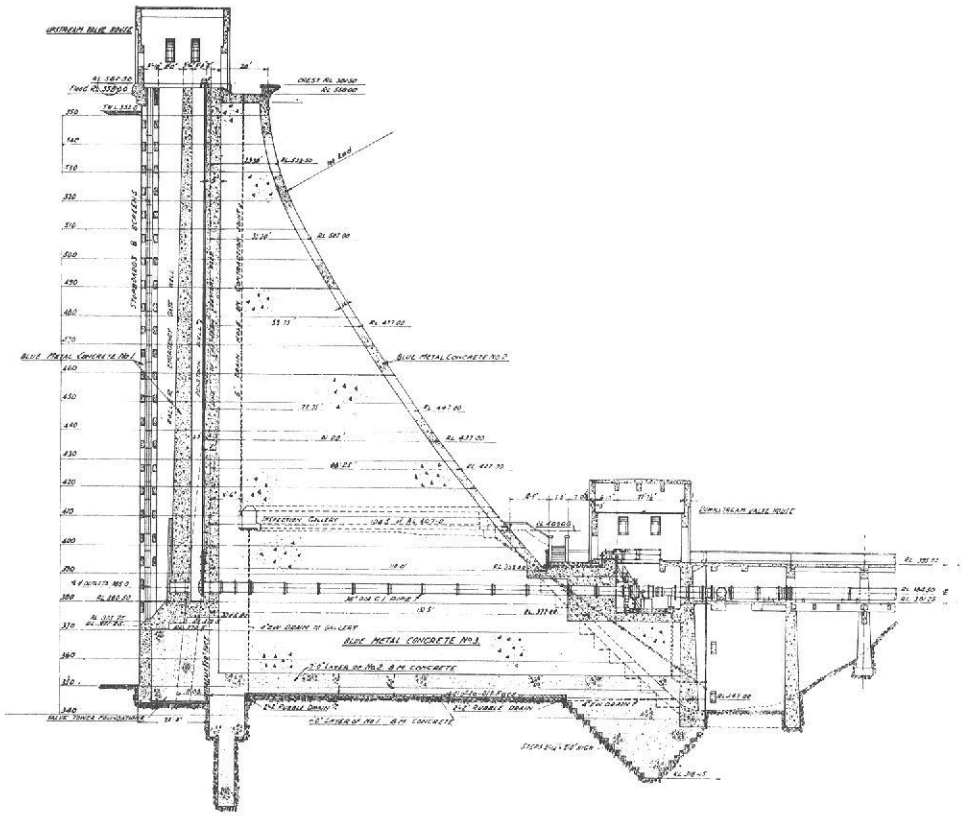
data that a dam could be constructed giving a total storage capacity of 12,500 million gallons, and a safe draught of 16 M.D.G. The cost of the dam was set down at approximately £1,000,000.

Delays took place in the completion of both Nepean and Woronora dams, due to the stringency of loan funds, and by the time opportunity arose to commence activity on O'Hare's Creek, additional data had indicated that, allowing for the standard of storage capacity approved by the Board on 13th July, 1938 (see Chapter X), the safe draughts that could be expected from Woronora and O'Hare's Creek were only 12 and 8.7 million gallons per day respectively. This entirely altered the relative economic aspects of O'Hare's Creek and Warragamba, as a result of which the Board on 13th July, 1938, approved the recommendation of its Engineer-in-Chief (Mr S. T. Farnsworth, B.Sc. (Eng.) Lond., M.Inst. C.E.), that it should abandon the O'Hare's Creek proposals and proceed to the development of the Warragamba River immediately. Mr Farnsworth proposed that this should be undertaken in stages, the first stage consisting of the construction of a 50-ft. weir on the river and of a pumping station in the rock beside it of a capacity of 40 million gallons per day. The water would be pumped by this via a 48-inch main to Prospect Reservoir 16 miles away, the requisite head being maintained by a balance reservoir of 7½ million gallons capacity at a high point above the pipe line near the station. The estimated cost of this work, together with that of the filtration plant which might be necessary at Prospect, was given as £975,000. The second stage (which would require to be completed about 1954) would consist of the rearrangement of the pumps to work in parallel, giving a capacity of 80 m.d.g., the construction of an additional main 72-inches in diameter, from the weir to Prospect, the enlargement of the filtration plant and additional balance reservoir capacity near the pumping station, the estimated cost being £880,000. The third stage (which would be required by about 1961) would necessitate the amplification of the pumping plant to 140 m.d.g., the laying of a second 72-inch main from the weir to Prospect, and the further amplification of the filtration plant at Prospect, the estimated cost being £935,000. The fourth stage (which would be required by 1968) would necessitate the construction of a dam 300-feet high, in accordance with earlier proposals together with the amplification of filtration plant, pipe lines and incidentals. These works were estimated to cost £2,622,000, and the dam to provide a safe draught of 225 m.d.g.

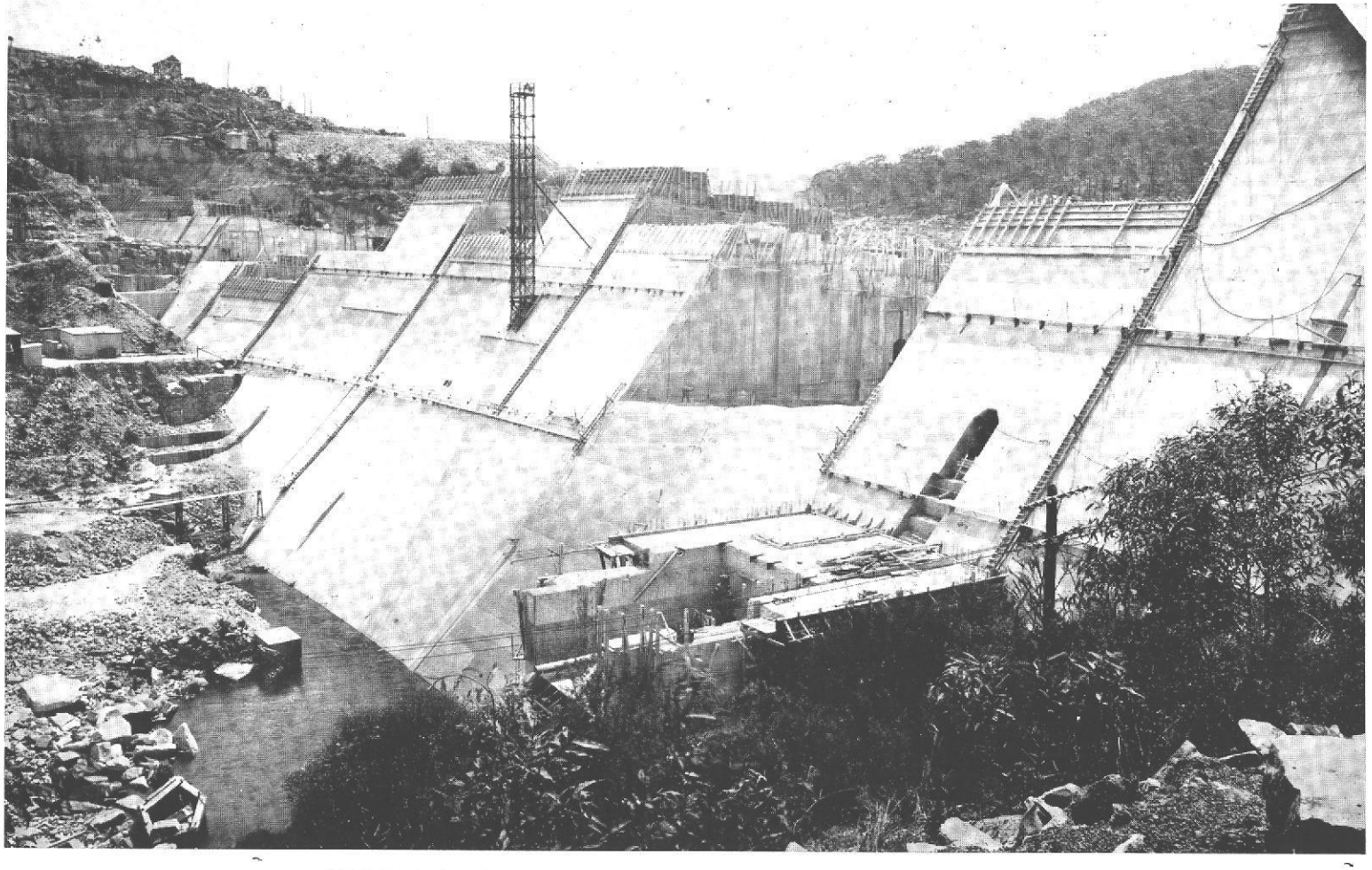
With this outline as a background, we will now proceed to a detailed description of the Woronora and Warragamba developmental works as carried out to date and projected.

Sutherland-Cronulla Water Supply System.

As has been explained in the foregoing, the Woronora Dam was undertaken with two ideas in mind—the one to supply storage for the



WORONORA DAM. TYPICAL CROSS SECTION.



WORONORA DAM IN COURSE OF CONSTRUCTION—5th JANUARY, 1939.

Sutherland-Cronulla Water Supply Scheme, the other to supplement and give an independent supply to the southern portions of the Metropolis. It was intended that the works associated with these two conceptions should go on concurrently, but owing to the incidence of the economic depression of 1930-32, this could not be done, and operations had to be adjusted to the completion of the Sutherland-Cronulla works by November, 1931, and further action suspended until January, 1936. Construction operations have therefore largely divided themselves into two distinct parts—the works necessary for supply to Sutherland and Cronulla, and those required to amplify these to enable the dam to give general metropolitan service.

The first supply of water to Sutherland Shire was given in 1911 by the laying of a 6-inch main from Penshurst Reservoir across George's River at Tom Ugly's Point to Miranda under guarantee by the Railway Commissioners to supply the Sutherland-Cronulla steam trams (discontinued in 1931). Subject to the consent of the Commissioners, householders along the route of the main were permitted to have the water laid on to their properties and were rated accordingly. Ultimately 121 houses were thus supplied. Not unnaturally, agitation soon arose for the amplification of this supply into a general service for the shire. This was not regarded as feasible, and attention was directed to the development of the neighbouring Woronora River catchment.

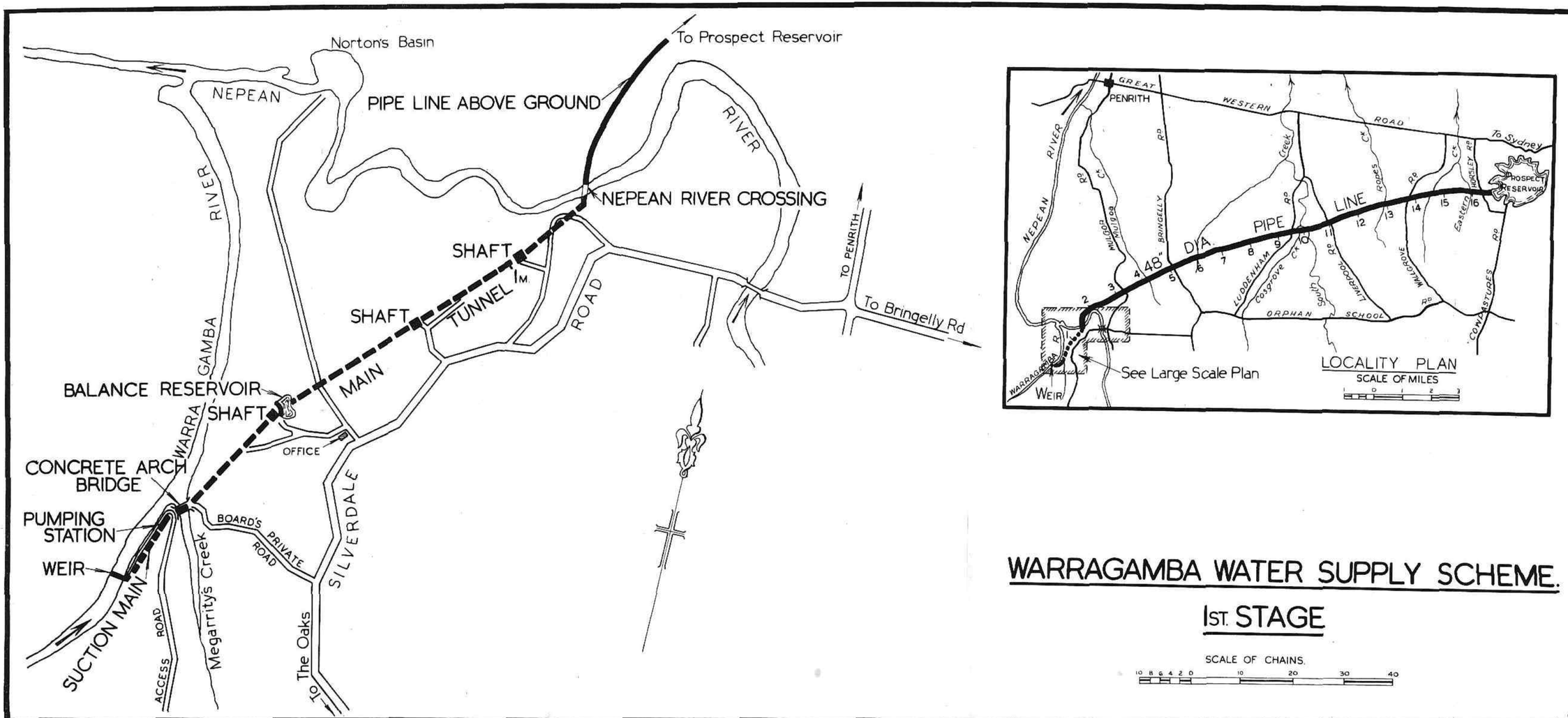
In 1920 a scheme to supply Sutherland-Cronulla from this source was prepared by the Public Works Department and referred to the Parliamentary Standing Committee on Public Works. After an enquiry extending over 10 months, during which considerable opposition to the separate scheme was shown on account of its cost, it was rejected. The opposition came chiefly from the people who believed that a cheaper supply from the general metropolitan system through Penshurst was practicable. The matter then lay in abeyance until 1925, when, following the establishment of the Board as the sole constructing authority of water supply works in the metropolitan area, the council renewed its application and in November, 1925, a scheme for supply of water from the Woronora River was agreed upon, as follows:—

	Estimated Cost.
Overshot Dam 60 feet high at the junction of Woronora River and Waratah rivulet, to impound 442 million gallons, with provision in the foundations for subsequent raising to 120 feet	£144,000
Trunk mains	195,000
Pumping Station, rising, outlet and reticulation mains, and local service reservoir	169,000
	£508,000

Allowing a deduction of £17,000 for the extra foundations to the wall not regardable as part of the Sutherland-Cronulla scheme, it was calculated that a water rate of 5s. in the £ of assessed annual value would be necessary in Sutherland Shire to make the scheme self-supporting. The Board, however, approved of a rate of 2s. in the £ and a charge for water by measure of 3s. per 1000 gallons. These rates were reduced from time to time and are now in line with those applying generally in the metropolitan area.

Construction was commenced in January, 1927, and was extended two years later to include the enlarged scheme previously mentioned. Work proceeded accordingly until March, 1930, when, owing to stringent financial conditions, the Board was compelled to suspend all major construction operations. In order to keep faith with the Shire Council which had been promised that the water supply would be available to the residents by December, 1931, a provisional scheme sufficient for the local supply was then formulated, and by arrangement with the Government, was gazetted in August, 1930, as a relief work to be carried out with funds provided by the latter from Unemployment Relief Account. This scheme was completed and formally opened in November, 1931, the particulars being as follows:—

The dam was constructed as a weir to a height of 45 feet above bed level, so as to impound 206 million gallons of water. Water from this dam is let down the river to a point seven miles downstream, where a concrete diversion weir constructed in the river bed immediately above the junction of Heathcote Creek with Woronora River provides a pool of 1·8 million gallons capacity from which the water is pumped through a 12-inch dia. mild steel cement lined rising main to a reinforced concrete service reservoir of 500,000 gallons capacity at Engadine. The pumping is done in two stages, the first stage being by means of three centrifugal pumps, electrically driven, two operating in series and the third serving as a stand-by, situated in a pumping station adjacent to the pool. These pumps lift the water to an upper station in which there are also three pumps designed for operation in the same manner as those in the lower station. The upper station is located alongside the ultimate position of the Woronora-Penshurst pipe line, and will form part of the permanent system. The power for operating the pumps is obtained from the Railway Commissioners along a high tension transmission line which has been erected from the railway line to a substation adjacent to the upper pumping station. Here the current is transformed down from 33,000 volts to 415 volts, by two Standard-Waygood, outdoor type, 150 K.V.A. transformers, a third and similar unit being available as a standby. The pumping is automatically controlled by a float switch operated by the rise and fall of water in the reservoir, and so arranged that the upper station pumps come into operation after



WARRAGAMBA WATER SUPPLY SCHEME.

1ST. STAGE

SCALE OF CHAINS.

A.A.B.

those at the lower station. At the inlet to the service reservoir, a water chlorination plant has been constructed. From the reservoir, water is supplied through a 15-inch machine-banded woodstave pipe line to Sutherland. (Two pressure reducing valves were installed on this line to regulate the pressure to the Sutherland area, but one of these has become unnecessary since the reservoir at Sutherland (see later) was completed). A 15-12-inch cast iron gravitation main, laid along the Kingsway, supplies water to Cronulla and intervening areas. The reticulation embracing Cronulla, Sutherland, Miranda, Caringbah and Burraneer, comprised nearly 28 miles of 6-inch and 4-inch cast iron cement lined pipes and 8 miles of 6-inch, 5½-inch, and 3½-inch fibrolite pipes. Since the completion of the initial scheme, a reinforced concrete service reservoir of a capacity of one million gallons has been erected at Sutherland (completed in 1936), in order to provide reserve storage for Cronulla during any interruption to pumping from Woronora River and to assist in meeting peak summer demands, while the mileage of reticulation mains has increased from 28 in November, 1931, to 98·818 miles at 30th June, 1937; the number of houses supplied from 2,170 to 3,390, and the population served from 9,244 to 14,444.

Owing to the exceptionally dry weather conditions which obtained during the summer of 1936-37, resulting in depletion of the storage in Woronora Dam, it became necessary to lay a 10-inch main across the George's River Bridge connecting with the main in Prince's Highway, Blakehurst, and to install a booster at that point drawing a supply from Penshurst Tanks. This temporary connection remained in operation for a period of three months from December, 1936, to March, 1937, when sufficient rain fell to render further use unnecessary. It is being retained as a safeguard against a recurrence of similar weather conditions until the enlarged Woronora Dam and pipe line are sufficiently advanced to ensure continuance of supply under all circumstances.

Extension of Woronora development for Metropolitan Purposes.

The amended scheme for metropolitan purposes as approved in January, 1929, provided for a dam 200 feet high and a 42-inch pipe line to Penshurst (altered in July, 1936, to 48-inch). Work proceeded on the foundations of the dam and the pipe track until November, 1930, when, for reasons that have already been outlined, operations were confined to the completion of the works just described. In June, 1935, the loan position having eased, the Board approved of the resumption of construction of the dam and pipe line, and since then work on both has proceeded uninterruptedly. It is anticipated that both works will be completed in 1940. A typical cross section of the dam is shown in the illustration opposite page 142, its details being generally similar to those

of the Nepean Dam. The pipe line will consist of mild steel spirally welded pipes, lined internally with $1\frac{3}{8}$ inches of cement mortar (applied by centrifugal spinning) and painted externally with a bituminous mixture and wrapped in hessian.

The catchment area was proclaimed and gazetted on 14th April, 1927 (33 square miles), and 21st November, 1930 (8 square miles).

Warragamba Development—First Stage.

The first stage of the Warragamba River development was commenced in April, 1937, as an emergency measure to supplement the Sydney water supply during the drought of 1934-1938. Indeed, it is proper to record that the economy of developing that source by stages instead of by proceeding to the main dam at once, was discovered during the investigation of the emergency problem. The weir, which is to be constructed 50 feet high, is being built upstream of the site of the main dam, and while it will impound sufficient water to supply the pumps which will operate pending the construction of the main dam, will ultimately serve with a downstream weir to unwater the river bottom upon which that dam will be built. Through the weir, two 6-ft. dia. pipes will be laid, the first to give immediate service to pumps supplying the 48-inch main now to be laid to Prospect, the other for subsequent use in the second and third stages of development. The pumping station which is being excavated in solid rock on the side of the river, will consist of a chamber 170 feet long by 35 feet high, with domed roof, and will be equipped with six horizontal centrifugal pumps arranged to pump in pairs in parallel, pumps in each pair being in series, and operated electrically. These pumps will lift the water through a 72-inch dia. pipe up a vertical shaft 190 feet high, and thence into the main leading to Prospect. This will pass via a reinforced concrete bowstring arch bridge (173-ft. span) over Megarrity's Creek into a tunnel 6,956 feet long, emerging at the bank of the Nepean River. The tunnel has been excavated to a dia. of 10 feet 4 inches, and will ultimately be filled with a steel liner, 8 feet 10 inches in dia. and surrounded with concrete. For the time being, it will, however, carry only a 48-inch pipe line. Leading from the tunnel, at a distance of 1,767 feet from its entrance at Megarrity's Creek, is a shaft, 152 feet high, which will connect with a surface reservoir of $7\frac{1}{2}$ million gallons capacity and top water level of 428 feet above sea level. Water in this reservoir will "float" on the pipe line and thus maintain evenly the head needed to give the requisite discharge of 40 m.d.g. at Prospect. It consists of a concrete arch of 160 feet radius, flanked on either side with gravity sections, and is being built across a natural gully. The pipe line will cross the Nepean River by being laid in and concreted into a trough excavated in the bed of the stream, and will then proceed overland to Prospect Reservoir.

A 132-ft. strip of land is being obtained to carry the full battery of pipes that will ultimately discharge to Prospect, the present 48-inch main being laid on the extreme northern side. Down the centre of the reserve, a concrete pavement 9 feet wide is being constructed. Valves will control the discharge at Prospect.

The degree of treatment required has not yet been determined, but it seems possible that for many years anything more than chlorination may not be necessary. This will be done at the pumping station so that ample time may be given the chlorine to take full effect while the water is travelling along its 16-mile journey.

It is anticipated that the work will be available to bring water to Prospect by the end of 1939.

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CHAPTER XVI

RICHMOND WATER SUPPLY

One further independent water supply scheme remains to be described, viz.—that serving Richmond. This was constructed by the Public Works Department and completed in 1892, and for some little time was operated by the Richmond Council. In May, 1893, the Board, at the request of the Minister for Public Works, took over the management of the system under similar conditions to those already described in respect of Wollongong, Richmond being outside the County of Cumberland. Proper legal transfer followed the passage of the Amendment Act, No. 13 of 1916, simultaneously with Wollongong.

The water is drawn from the Hawkesbury River by pumps situated in a station on its left bank below the confluence of the Grose and the Nepean Rivers and is discharged into a circular brick service reservoir; 60 feet in diameter, with a capacity of 256,000 gallons. From this it is distributed to Richmond. Up to 1910, it also served the Hawkesbury Agricultural College, but since that year, when the College established its own pumping scheme, water has only been supplied to that institution when its own plant has been out of action. Prior to 1911, the water drawn from the river was not treated, but in that year a Candy filtering plant was established near the pumping station, and since then all water has been filtered before issue.

The original pumping plant consisted of Colonial tubular boilers and two horizontal 6 H.P. engines, working two brass-lined single barrel deep well pumps (Tangye). In 1918, this was replaced by electrically operated plant, comprising two 35 H.P. 2000 volt 60 cycle 3 phase motors driving duplicate centrifugal pumps, the motors being at ground level and the pumps (vertical spindle type) below them at the bottom of a new shaft 60 feet deep. Power was obtained from the Hawkesbury College, three miles distant. In 1923, the College changed the periodicity of its electrical energy to 50 cycles, and it became necessary for the Board to provide new motors and pumps. These were installed in April, 1925, comprising two vertical spindle 4 inch 4 stage centrifugal pumps, each direct coupled to one of two 35 B.H.P. motors by vertical shafting. Their capacity is 13,000 gallons per hour against a head of 255 feet. During the change, the old steam plant was brought back into use. In 1929,

a 45 B.H.P. "Jelbart" engine was added as a standby to this plant, driving the old reciprocating Tangye pumps.

The distribution system consisted originally of a 6-inch supply main from the service reservoir to Richmond, 4 miles in length, and $5\frac{1}{8}$ miles of reticulation mains, 3-inch and 4-inch in diameter, within the town. This was steadily added to until in 1926 an elevated service reservoir was erected in the town near Church Hill to maintain pressure during the hours of peak loading and to give some reserve against interruption of supply. This is built of cast iron plates and supported on a steel tower. Its capacity is 53,000 gallons, and top water level 142 feet above sea level. The 6-inch supply main to the town was then renewed in 8-inch pipes for portion of its length. From this point a second line of 6-inch pipes was laid to the elevated reservoir parallel to the original main. The supply of coagulant to the filtration plant was also improved in the same year by the installation of a Candy standard diaphragm pump with a capacity of 8-12 gallons per hour, driven by a $\frac{3}{8}$ B.H.P. 220 volt, 50 cycle, single phase motor. During 1936, the reticulation was further improved by the replacement of the original 3-inch mains with 4-inch cement lined cast iron pipes, and in the following year, a number of other sections were amplified by replacement with larger pipes. At 30th June, 1938, the mileage of water mains had reached 16 miles.

In 1924, when the Commonwealth Government established the Richmond aerodrome, negotiations were opened with the Board for the extension of the Richmond water supply to the aerodrome, but later on, the Commonwealth Authorities arranged for a supply from the separate scheme operated by the Hawkesbury Agricultural College. With the recent expansion of defence activities an increased supply of water for the Air Force located there has become necessary, and negotiations are at present in hand which have as their objective the combination of the Richmond and the College systems into one unit and the carrying out of any further extensions on a district basis.

The following table shows the growth of the system:—

Year	Capital cost	Population served	Quantity of water supplied Gallons	Average daily consumption per capita Gallons
1894 ..	12,340	885	7,790,000	24
1904 ..	12,817	1,275	16,275,000	35
1914 ..	15,811	1,495	14,577,000*	27
1924 ..	23,145	2,055	24,534,000	33
1938 ..	39,642	2,621	36,164,000	38

* Hawkesbury Agricultural College ceased to draw from the town water supply in 1910.

CHAPTER XVII

WATER SUPPLY RETICULATION

When the Board took over the control of the water supply system in 1888, the reticulation had extended into the following suburbs: Alexandria, Ashfield, Balmain, Burwood, Camperdown, Darlington, East St. Leonards (now North Sydney), Glebe, Leichhardt, Marrickville, Newtown, Paddington, Petersham, Randwick, Redfern, St. Leonards (North Sydney), St. Peters, Strathfield, Victoria (North Sydney), Waterloo, Waverley and Woollahra, and the length of watermains underground was 355 miles. Of these, about 200 miles were of 3-inch and 4-inch diameter, 75 miles of 6-inch diameter, and the balance of larger sizes, being trunk and pumping mains.

The watermains in use by the Board originally were all cast iron or wrought iron, and were dipped in a bath of tar or bitumen for protection. The use of these materials continued until the introduction of steel pipes for mains of large diameter. Since centrifugally applied cement linings have been used, the construction of such mains in steel has been the general practice.

The water from the Nepean catchment is soft and slightly acid, as will be seen from the following typical analysis:—

Colour (U.S. Platinum Scale)	23·0	
Chlorine, in Chlorides	2·40	parts per 100,000
Nitrogen in Free Ammonia	0·0004	„
„ „ Alb. Ammonia	0·0090	„
„ „ Nitrites	0·0	„
„ „ Nitrates	0·0027	„
Oxygen absorbed from Permanganate	0·0894	„
Iron	0·0320	„
Alkalinity as $CaCO_3$	1·0	„
Total Hardness	1·8	„
pH	6·8	

It is therefore liable to corrode iron or steel mains, and about 1910, in an endeavour to reduce this attack, woodstave mains were introduced. These have not proved entirely satisfactory and since 1934 with the development of other alternatives, no woodstave mains have been laid. The most important alternative is the lining of cast iron or steel

mains with cement mortar. This was first done in 1925 when the No. 3 72-inch main from Pipe Head to Potts Hill was laid, and a lining of cement mortar was centrifugally applied. In the next two years, a section of the 30-inch Waverley rising main, the 36-inch-30-inch-24-inch Potts Hill to Wattle Hill main, and the 24-inch Woollahra to North Bondi main were laid with similar pipes, and the No. 1 and No. 2 72-inch mains from Pipe Head to Potts Hill were cement lined in place, and by 1929 the process had so proved itself that the policy of cement lining all metal pipes before laying was established.

Concurrently with the development of cement lining, trials were being made overseas of other materials for pipes, and on the recommendation of Mr J. G. S. Purvis, then Chief Engineer, a quantity of "Eternit" cement asbestos pipes were imported for trial purposes. These were laid in 1927 and proved satisfactory, and by 1930 the local manufacture of fibrolite pipes of similar composition had been developed, and the first sections of main of this type were laid in that year. They are now in use up to 8 inches in diameter, being confined, however, to rural areas where frequency of connection of service pipes is less than in the suburbs, and to situations where the pressure head does not exceed 300 feet.

At this stage, the Board had thousands of miles of unlined cast iron mains which were still being corroded and so losing capacity and requiring cleaning from time to time. In addition, while new pipes could be lined centrifugally with cement mortar, the process was not applicable to bends. In 1931, experiments with the cement lining of bends were commenced at the instance of one of the Board Members, Mr W. T. Tate, which were later extended by him with the co-operation of the Board's technical staff, to the development of an apparatus for cement lining pipes already underground. It was realised that if this could be accomplished, substantial savings would accrue from the prolongation of the efficient life of the metal mains; further, the quality of the water would be gradually improved as the treatment extended through the reticulation system by the prevention of internal corrosion with its discolouring effect on the water.

Arising out of these experiments, Mr Tate secured a patent (No. 3192/31, dated 23rd July, 1931), for an invention described as "an improved apparatus for lining pipes with cementitious material." This patent has particular reference to a metal skirt with dehydrating orifices attached to the projectile spreader carrying the cement along the barrel of the pipe. This dehydrating skirt, being designed for use with "wet" cement mortar, necessarily involved the development of apparatus for loading the mortar into the pipe. In 1932, trials were made by the Board's technical officers and a length of nearly one mile of 4-inch main was successfully lined. Following these trials the Board's

engineers (Mr G. Haskins, then Chief Engineer, and Mr S. T. Farnsworth, then Water Engineer) developed a process, referred to as the "dry" process, of using a cement mortar of greater consistency than that used with the "Tate" spreader and skirt. For this a device termed a "preliner" or distributor to carry the comparatively dry mortar along the pipe ahead of the spreader was designed, the latter having a slotted dehydrating skirt of a somewhat different character to that used in the "wet" process. This alternative process is also covered by a patent (No. 10380, dated 30th November, 1932), termed "an improved process and apparatus for lining pipes *in situ* with cement mortar."

The Board holds licenses from both patentees covering the free use of the "wet" and the "dry" processes of cement lining, and any improvements in such processes or apparatus connected therewith which may be invented from time to time. Since both processes have been in use, the methods of operation have been carefully watched and improved. Early in 1937, operations which up to that time had been confined to mains of 4-inch diameter, were extended to the lining *in situ* of mains of 6-inch diameter. The total mileage of 4-inch mains cement lined *in situ* since the commencement of these operations in July, 1932, to 30th June, 1938, is 688 miles, and of 6-inch mains, 72 miles. There still remain about 3,000 miles of unlined mains underground in the system. The rate of progress has been much accelerated in the more recent years, as experience has enabled improved organisation to be introduced, and at present is proceeding at the rate of over 200 miles per annum.

The total cost of lining the 760 miles of mains dealt with to date is approximately £289,000, including supervision and overhead charges. This works out at about 4s. 3d. per lineal yard, which is less than one-fourth the over-all cost of providing a new main. The old main, when cleaned, scraped and cement lined, has a renewed life equal to that of a new pipe.

The cost of cement lining mains that are not new is apportioned to Capital and Revenue respectively, according to a formula based on the number of years added to the life of the unlined main compared with the life that has already passed. For example, in respect of a pipe cement lined after being underground for 15 years, four-sevenths of the cost is capitalised and three-sevenths treated as renewal expenditure. In cases where the pipes have been underground for 30 years or more, the cost of cement lining is charged wholly to renewals.

In recent years, the construction of cement concrete pipes has improved greatly, and such pipes are now available for water supply use. Except in isolated cases, such as that already mentioned at Upper Cordeaux, and portion of the Ingleburn outlet main, concrete has not been used by the Board for watermains.

At 30th June, 1937, the length of mains in use had reached 4,031·467 miles, made up of the following sizes and types:—

Size of main	Cast Iron and Steel				Reinforced concrete	Wood-stave	Fibrolite
	Unlined	Cement lined in situ	Cement lined	Bitumen lined			
inches	miles	miles	miles	miles	miles	miles	miles
1				gal. ·126			
1¼				·028			·228
3	32·100						
3½							131·936
4	1,591·723	538·050	461·901			40·451	
5	2·772						
5½							29·663
6	630·894	7·190	109·721	·040		25·037	
8	149·024		38·158			3·597	
9	65·156						
10	142·190		30·911			5·021	
11	2·000						
12	122·826		35·696	3·260		6·329	
14	·043					3·888	
15	82·153		37·681		1·429	11·869	
18	41·252		6·737		·865	·073	
20	61·012		10·397	2·015		2·555	
24	56·849		15·071			1·538	
28	4·894						
30	28·351		15·956		1·859	7·236	
32	13·766					·587	
33½			5·809				
36	33·244		8·061				
42	7·957						
44						·419	
46						4·466	
48	28·803		4·021				
54						5·465	
60	·473		·003				
72			15·179	5·455			
	3,097·482	545·240	795·302	10·924	4·153	118·531	161·827

Total .. .. 4,733·459 miles

less abandoned and exhumed mains .. 701·992 „

4,031·467 miles

Following on the development of a high class bituminous lining for the Pressure Tunnel, some use was made of bitumen linings for the protection of steel mains, notably in the upper (Prospect-Pipe Head) 72-inch main. For general use, however, the cement mortar lining, centrifugally applied, is usually adopted. In all recently laid, cement lined, large steel mains, a bituminous protecting coat has been applied internally before the cement lining was placed, to protect the steel from attack by any water penetrating the lining, while a bituminous emulsion coat is now applied to the interior of large and small cement lined pipes as a protection against the leaching out by the water of soluble components of the mortar coating.

Experience with steel and wrought iron mains laid many years ago, has indicated the need, in certain districts where soils or ground waters are aggressive, for better external protection of such pipes. Various improved coatings, using hessian wrappings and bituminous compounds, have been developed, and special protection is now given to the joints of large mains, both internally and externally. Large steel mains are now further protected against corrosion by being laid in sand filling.

The determination of the type of pipe to be used should not be merely on the basis of first cost. When alternatives are being considered, the probable time of renewal of the main is allowed for in determining the comparative values of various types of construction.

For metal pipes, the use of poured lead joints was the general practice from the inception of the Board, but with the development and extensive use in America of proprietary jointing compounds with a sulphur base, these were used experimentally on mains in the Sydney system. As experience was gained, such compounds were used more frequently until by 1930 their use became general for cast iron pipes. In 1933 a joint of this type on a large steel main was found to have corroded the metal extensively and the use of such compounds has been abandoned for steel mains since 1933, and for cast iron mains since 1937. For fibrolite pipes and certain metal pipes, rubber ring joints of the Gibault type have been used, while more recently sockets and push-in rubber ring joints have been adopted.

Hydrants on reticulation mains in the Board's earlier years were of the wooden plug type, but these were later superseded by the ball hydrant with lugs for the attachment of the standpipe. Subsequently, these hydrants were generally replaced by spring hydrants in the suburban and outer areas and screw-down hydrants in the city zone. The use of concrete and bituminous concrete for road surfaces gave rise to demands for the removal of the mains from the roadways and in many instances rider mains were laid on both sides of the road where such surfaces were being constructed. An agreement was made with the Main Roads Board as from 1st July, 1926, for the sharing of the cost involved in

such work, and an understanding with the City Council for payment of a share of the cost was, in November, 1937, replaced by similar agreement. With the development of machines for laying pipes under hard surfaces by thrust boring, it has been possible to dispense with the duplicate mains in a number of instances, with a great saving in expenditure.

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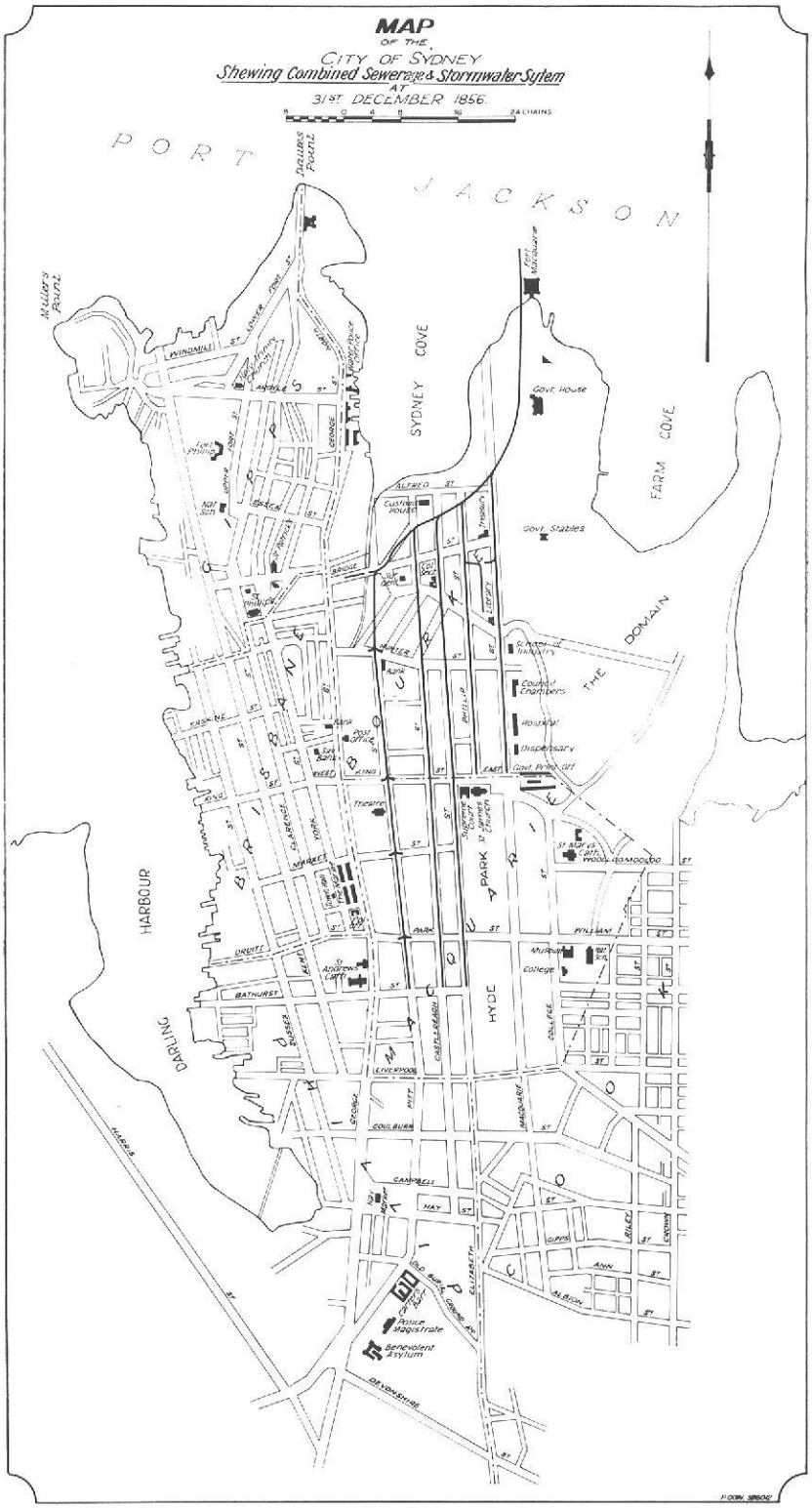
"Maintenance and Protection of Cast Iron Water Pipes," by F. W. F. Waitt, M.C.E., A.M.I.E.Aust., Trans.I.E.Aust., Vol. XV, 1934, p. 298

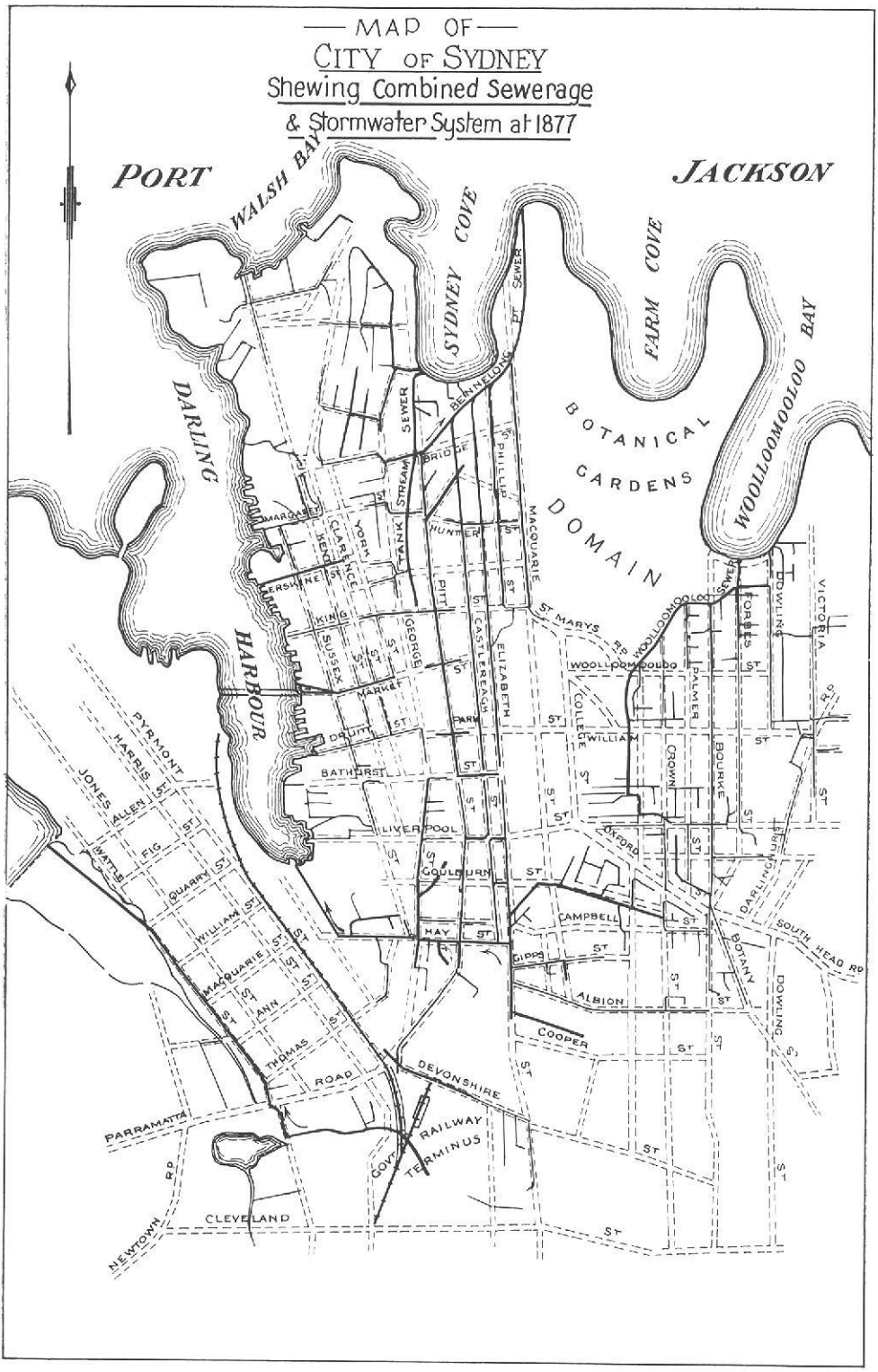
CHAPTER XVIII

INITIAL COMBINED SEWERAGE AND DRAINAGE SYSTEM UNDER CITY COUNCIL'S CONTROL—1857-1889

The streams which formed the source of water supply to the first settlers at Sydney Cove in 1788, of which the principal one was the Tank Stream, were gradually transformed into open sewers with the growth of the settlement. Occupation due to the establishment of industries and erection of houses in the catchment basins of these streams caused them to become polluted to an increasing extent, until their dry weather flow was largely composed of fouled or slop water. In course of time it became necessary, owing to the spread of pestilence and disease, to commence the construction of underground sewers to take the place of the polluted surface streams.

In 1842 an Act (6 Vic. No. 3) was passed declaring the town of Sydney to be a City, and providing the constitution of a City Corporation or Council. One of the most urgent responsibilities cast upon the Council was the provision of proper surface and underground drainage. Several years passed without the Council taking any definite action to discharge this responsibility. The limitations of its financial resources were recognised as being in a large measure responsible for its inaction, but there was a lack of confidence on the part of the Government and the public regarding its ability to deal effectively with the important civic matters entrusted to it. This culminated in an Act being passed dissolving the Council, and providing for the appointment of three Commissioners to supersede it from the 1st January, 1854. An Act (17 Vic. No. 34) was also passed, authorising the Commissioners to commence the sewerage scheme and providing for the raising of a loan of £200,000 by the Government for this purpose. The necessity for the sewerage system had then become so urgent that Parliament, impatient at the apparent delay by the newly constituted Civic Commission in commencing the work, appointed a Select Committee of the Legislative Council in October, 1854, to investigate the matter, more particularly the action of the Commissioners in first having a complete trigonometrical survey of the City made, as it was considered this was mainly responsible for the delay. The Select Committee, in its report, expressed


MAP
OF THE
CITY OF SYDNEY
Shewing Combined Sewerage & Stormwater Sytem
AT
31ST DECEMBER 1856.
24 CHAINS
PORT JACKSON
DAWES POINT
MILLER'S POINT
SYDNEY COVE
FARM COVE
THE DOMAIN
HARBOUR
DARLING
HYDE PARK
Govt. House
Govt. Stables
Custom House
Council Chambers
Hospital
Dispensary
Govt. Printing Off.
Police Magistrate
Benevolent Asylum
Museum
College
Theatre
Post Office
Treasury
Supreme Court
St James Church
St Andrews Cath.
Govt. Domain
Govt. Printing Office
Lunatic Asylum
Circular Quay
Fort Macquarie
Lavinia Place
Argyle St
George St
Sussex St
Kent St
York St
Clarence St
Pitt St
Castlereagh St
Elizabeth St
Macquarie St
Phillip St
Bridge St
Collins St
Ann St
Albion St
Liverpool St
Bathurst St
Goulburn St
Campbell St
Hay St
Market St
Park St
William St
Druitt St
Devonshire St
Harris St
Alfred St
Essex St
Crescent


MAP OF
CITY OF SYDNEY
Shewing Combined Sewerage
& Stormwater System at 1877
PORT JACKSON
WALSH BAY
SYDNEY COVE
FARM COVE
WOOLLOOMOOLOO BAY
DARLING HARBOUR
BOTANICAL GARDENS
DOMAIN
BENNELONG PT SEWER
SEWER
BRIDGE
STREAM
TANK
MARGARET ST
YORK ST
CLARENCE ST
KENT ST
HUNTER ST
PHILLIP ST
MACQUARIE ST
PITT ST
CASTLEREAGH ST
ELIZABETH ST
GEORGE ST
KING ST
SUSSEX ST
MARKET ST
DRUITT ST
BATHURST ST
LIVERPOOL ST
GOULBURN ST
HAY ST
PARK ST
COLLEGE ST
WILLIAM ST
ST MARYS RD
WOOLLOOMOOLOO
PALMER ST
BOURKE ST
CROWN ST
OXFORD ST
CAMPBELL ST
DIPPS ST
ALBION ST
COOPER ST
DEVONSHIRE ST
RAILWAY TERMINUS
GOVT
PARRAMATTA RD
NEWTOWN RD
CLEVELAND ST
ROAD
THOMAS ST
ANN ST
MACQUARIE ST
WILLIAM ST
QUARRY ST
FIG ST
WATTLE ST
JONES ST
HARRIS ST
PYRMONT
ALLEN ST
DARLINGHURST
BOTANY
SOUTH HEAD RD
DOWLING ST
VICTORIA ST

the view that plans and survey information available in the Surveyor-General's office might have been made use of and an early start made with the work. The City Commissioners then proceeded with all haste to construct five main outfall sewers in brick and stone, and the work was continued by the City Council which again took over control of the City's affairs in January, 1857. These outfall and tributary sewers discharged into the harbour at Blackwattle Bay, Darling Harbour, Sydney Cove (Circular Quay), Fort Macquarie, and Woolloomooloo Bay. In addition, minor sewers were placed in almost every street and watercourse leading directly to the Harbour for outfall.

The following are the particulars of the outfall sewers:—

1. Wattle Street sewer, brick, 6-ft. by 4-ft., discharging into Blackwattle Bay.
2. Hay Street sewer, stone, 7-ft. by 10-ft., with semi-elliptical roof, and the Darling Harbour Railway sewer, brick, 5-ft. by 4-ft., each discharging into Darling Harbour.
3. Tank Stream sewer, stone invert, brick sides, and arched top, 4-ft. 6-ins. by 10-ft., discharging into Sydney Cove.
4. Fort Macquarie sewer, brick, 6-ft. by 4-ft. oviform, with branch oviform sewer 3-ft. 6-ins. by 2-ft. 4-ins. from Bridge Street and other tributaries discharging into Sydney Harbour at Benelong Point.
5. Woolloomooloo sewer, built of stone, 6-ft. by 10-ft. with semi-elliptical roof discharging into Woolloomooloo Bay.

In 1889, when the Board of Water Supply and Sewerage took over the City sewerage system from the Council, the latter body had constructed about 6¼ miles of main sewers and 64 miles of subsidiary sewers, serving about 18,000 houses. These old City sewers convey stormwater and surface drainage as well as sewage, and although the intercepting sewers of the Main Northern system (Bondi Ocean Outfall) completed by the Government in 1889, originally diverted the flow from all areas above the gravitatable limit to the ocean, and the City low level sewers completed by the Government about 16 years later diverted the flow below that level, the increase in the volume of sewage in the City sewers under the combined system (fouled water and stormwater) has gradually diminished the benefit of these interceptions, until in later years it has only been completely effective for the carriage of the normal dry weather flow.

The old City Council sewers were laid for the most part at an effective depth of about 9-ft.; this generally is too shallow to drain the basements which exist in most of the more modern structures erected in the City. The Board, therefore, has adopted the policy for many years back

of laying deep sewers capable of draining a basement of one floor in cases where these new buildings were erected. As these deep sewers become available, the owners of all new buildings which can be so sewered are required to install separate drainage systems for roofwater and fouled water respectively, connecting the former to the old City sewer and the latter to the new deep sewer. In every case where structural alterations to buildings involving existing drainage arrangements are being carried out, and separate sewers are available, similar separation of the private drains is required. In this way, the separation of stormwater and fouled water in the City sewerage system is gradually taking place, but the process is necessarily a slow one. The work of completely superseding the old combined system sewers throughout the City has been recently tackled on a comprehensive basis, and is being carried out as expeditiously as funds and the magnitude of the work, together with the difficulties connected with construction operations in the busy City thoroughfares will permit. After the separate fouled water system has been completed, the old City sewers will function solely as stormwater ducts. The co-operation of City property owners in meeting the Board's requirements regarding alterations to the private drains is an important factor. This co-operation, which is for the general good in the minimising and ultimate prevention of nuisance along the Harbour frontage, and the reduction of risk of surcharging of sewers in times of heavy storms, is something which the Board looks forward with confidence to receive, otherwise the large expenditure involved in installing the separate fouled water sewerage system in the City will only yield partially effective results.

In January, 1890, when the Board of Water Supply and Sewerage assumed practical control of the sewerage of Sydney and suburbs, the extent of the area served was as follows:—

	Mileage of sewers	No. of houses served
City of Sydney	70.27	18,000
Darlington	2.11	716
Paddington	10.39	3,207
Redfern	3.2	2,819

The sewers in the three suburban districts named above were constructed by the Government on behalf of the councils concerned, with funds raised by these bodies by the issue of debentures. The sewers drained into the main Government sewers (Northern and Southern Outfalls)

which had at the time been completed to an extent enabling this to take place. Being even at that time thickly settled districts, the respective Councils were evidently laudably anxious to have the advantages of an underground sewerage system at the earliest opportunity. The sewers constructed by these Councils were taken over by the Board in 1890, together with the debenture indebtedness attaching thereto.

REFERENCES

Act (17 Vic. No. 34) passed in 1853, appointing Commissioners to replace City Council with power to initiate Sewerage and Drainage schemes for Sydney.

Final Report of Select Committee on Sydney Sewerage and Water Appropriation Bill, 1854.

"Sydney Morning Herald," 8th January, 1873.
do. 7th April, 1873.
do. 10th January, 1874.

Water and Sewerage Bill passed 6th March, 1874, appointing Sewerage and Health Board.

Paper "City Government by Commission," by F. A. Bland, M.A., LL.B. Vol. XIV, Part 3, 1928, Journal and Proceedings, Royal Historical Society.

CHAPTER XIX

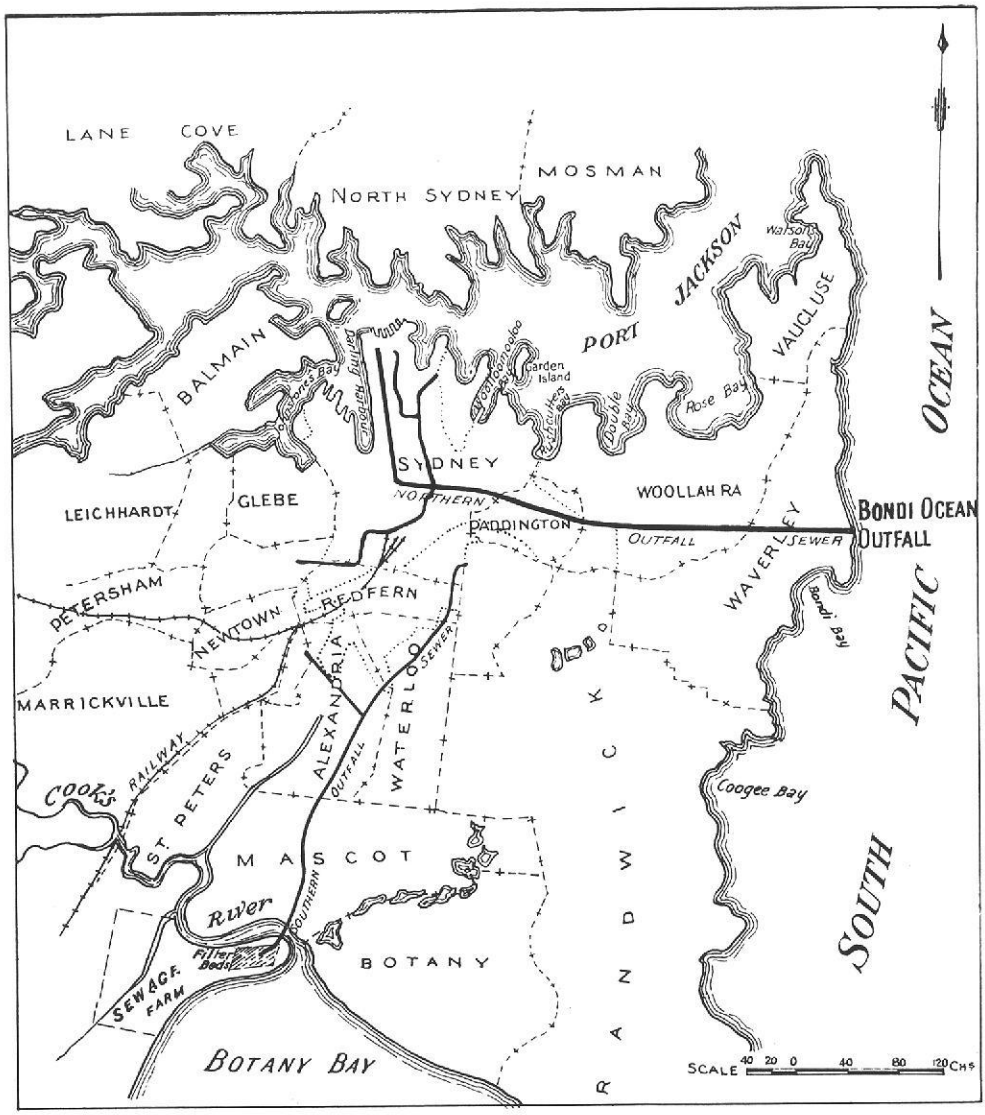
GOVERNMENTAL (SEWAGE AND HEALTH BOARD'S) SCHEME OF 1877 FOR INTERCEPTION OF HARBOUR OUTFALL SEWERS

In 1873, the Government constituted a body called the Sewage and Health Board, whose principal function it was to draw up a scheme of sewerage for Sydney and suburbs which would include the provision of sewers to intercept, as far as levels would permit, the sewage which was discharged into the Harbour by the City Council's main sewers and was causing a nuisance to be set up to an increasing extent. This body included two prominent engineers in the service of the Government, viz., Messrs. E. O. Moriarty, M.A., M.Inst.C.E., and W. C. Bennett, M.Inst. C.E. The former was subsequently prominently associated with the construction of the Upper Nepean Water Supply Scheme, and the latter with the construction of the main Government sewerage works as well as being one of the original Government nominee members of the Board of Water Supply and Sewerage.

The Sewage and Health Board formulated two separate schemes, viz:—

1. Northern System with outfall into the ocean at Ben Buckler (Bondi) providing intercepting sewers for the Harbour outfall sewers, together with branch sewers for completing the sewering of the City and suburbs draining in a northerly direction towards the Harbour.
2. Southern System with outfall at a sewage farm (Botany Bay), providing main and branch sewers to serve the southern slopes of the City and suburbs draining towards Shea's Creek and Botany Bay.

The recommendations of the Sewage and Health Board were submitted to and endorsed, with minor alterations, in 1877 by Mr. W. Clark, M.Inst.C.E., an eminent English engineer, who had been brought out by the Government to advise it on various water supply and sewerage schemes promulgated for Sydney and suburbs. The two sewerage schemes were carried out by the Government, construction work being com-



OUTFALL WORKS ADDED TO GENERAL SYDNEY SYSTEM, 1880-1890.

menced in 1880 and completed in 1889. They were transferred to the Board of Water Supply and Sewerage in January, 1890. The schemes are described and their subsequent development dealt with in Chapters XX and XXI.

REFERENCES

Sydney City and Suburban Sewage and Health Board.

1st	Progress Report,	4th May, 1875
2nd	do.	24th June, 1875
3rd	do.	14th July, 1875
4th	do.	25th August, 1875
5th	do.	18th October, 1875
6th	do.	8th November, 1875
7th	do.	3rd January, 1876
8th	do.	8th February, 1876
9th	do.	4th April, 1876
10th	do.	2nd May, 1876
11th	do.	10th August, 1876
12th	(Final)	11th May, 1877

CHAPTER XX

NORTHERN (NOW BONDI) OCEAN OUTFALL SYSTEM

The original works connected with the outfall and intercepting sewers of the Northern (Bondi Ocean Outfall) system constructed by the Government, which were completed in 1889 and transferred to the Board of Water Supply and Sewerage by proclamation dated 18th December, 1889, may be described as follows:—

At the outfall at "Ben Buckler" a large chamber 30-ft. long, 24-ft. wide, and 31-ft. high, was cut out of the sandstone rock from which a ventilating shaft 12-ft. by 5-ft. was erected to a height of 55-ft. 6-ins. above ground level, and 197-ft. 6-ins. above the invert of the main sewer at that point. From this chamber, two circular outlet channels each 4-ft. in diameter were constructed, one heading north-easterly and the other south-easterly, so that in times of storm one outlet would be less affected by wave action than the other, and this wave action would expend itself by going up one opening and out at the other. The exits of these channels were clear at low water, with the result that at times air compression due to wave action forced sewer gases to escape where possible. Action was taken to avert this in 1930, when the south-eastern discharge channel was lowered to a depth of 17-ft. below the lowest spring tides, and the north-eastern channel was closed up. Wave action then produced no ill-effect by air compression in the main sewer, and the alteration demonstrated that a single channel of sufficient depth is effective under all weather conditions at this point. The ventilating shaft developed serious cracks and flaws in later years, and it was demolished in 1910 and a circular reinforced concrete shaft erected to a height of 100-ft. above the ground. The maximum internal diameter is 12-ft. and minimum internal diameter at top is 7-ft. 2-ins.

The main sewer is laid from the outfall chamber at Bondi in a westerly direction crossing Double Bay Valley to Liverpool and West Streets, thence along Liverpool Street to Oxford and College Streets. The dimensions of this sewer at the chamber referred to are 8-ft. 6-ins. by 7-ft. 6-ins., which gradually diminish to 6-ft. 10-ins. by 5-ft. 10-ins. at the junction chamber at Oxford and College Streets, from which the main branches extend in northerly, westerly and south-westerly directions and may be described as follows:—

1. *Northern Main Branch*—Proceeds from the junction chamber under Hyde Park to Castlereagh Street at Martin Place where it bifurcates, one submain continuing along that street under private property and other streets to Macquarie Street, terminating near Albert Street, and intercepting to the gravitation limit, sewage which formerly discharged into the Harbour at Fort Macquarie (Benelong Point). The other submain is laid in Martin Place and George Street and thence in Margaret and other streets and private property, terminating at Argyle Street, intercepting to the gravitation limit the western flow of he Tank Stream sewer, the outlet of which is at Circular Quay. Dimensions of this sewer vary from 4-ft. 6-ins. by 3-ft. to 3-ft. 3-ins. by 2-ft. 2-ins.

2. *Western Main Branch* which extends from the junction chamber at Oxford and College Streets, along Liverpool and Kent Streets to Windmill Street, intercepting to the gravitation limit sewage formerly discharged into Darling Harbour. Dimensions 4-ft. 6-ins. by 3-ft., 3-ft. 6-ins. by 2-ft. 4-ins., and 3-ft. 3-ins. by 2-ft. 2-ins.

3. *South Western Main Branch*—Proceeds from the junction chamber under private property, several streets, Belmore Park and the Central Railway Station and along George Street West to Jones Street, where it is joined by a submain, which passes through Darlington, University Grounds, and Camperdown, intercepting old City sewers and providing for the reticulation of Darlington, Camperdown and Newtown. This submain is known as the Prince Alfred Hospital branch and in the original construction terminated at the University Grounds. In 1893 the extension of this, known as the Camperdown branch, was completed to Liberty Street, Newtown, by the Government, and transferred to the Board in that year. A second submain off the South Western Main Branch was constructed and transferred to the Board in 1893, extending along Jones Street, Pyrmont, and terminating at the corner of Allen Street and Bulwarra Road, intercepting old City sewers. Dimension 3-ft. 3-ins. by 2-ft. 2-ins. to 9-inch pipe. This submain has since been duplicated by the Board, in pipes ranging from 21-inches to 9-inches diameter.

Another important branch sewer passes along George Street West from Balfour Street to Bay Street, by a long syphon on account of the depression in the ground. Connected with the syphon, a scour chamber with valves and overflow for periodic cleansing was constructed. From Bay Street it extends with numerous branches to the Glebe, Leichhardt and Balmain. In addition to providing for reticulation of the suburbs named, this main sewer intercepts the whole of the sewage above the 40-ft. contour line which formerly flowed into Blackwattle Bay. The sewer is carried across Johnston's and White's Creeks on long monier aqueducts.

The dimensions of the foregoing main branch sewers vary from 5-ft. 10-ins. by 4-ft. 10-ins. to 3-ft. 3-ins. by 2-ft. 2-ins.

Between the outfall at Bondi and the junction chamber at Oxford and College Streets, from which the main branch sewers extend to the City, Darlington, Newtown, Annandale, Leichhardt, Glebe, and Balmain, the following large sewers junctioning with the Outfall Sewer were constructed by the Government and transferred to the Board in the years as stated below. These sewers provided for the reticulation of East Sydney, Paddington, Woollahra, and Waverley.

1893.

Waverley and Woollahra Branch, which extends from the Bondi main sewer along the eastern side of Double Bay Valley and passes under Edgecliffe Road to Denison and Birrell Streets, Waverley.

Elizabeth Bay Branch, which joins the main Bondi sewer at Great Barcom Street and extends along the western side of Rushcutters Bay Valley intercepting a considerable quantity of the sewage which formerly discharged into that Bay.

Bourke Street Branch, which joins the main Bondi sewer at Bourke and Liverpool Streets near Darlinghurst Court House and extends along that street for some distance, then passing into Victoria Street and terminating at Billyard Avenue, intercepting sewage which formerly discharged into Woolloomooloo Bay.

1894.

Darling Point Branch, which joins the main Bondi sewer near Harris Street, Paddington, and extends along the eastern slopes of Rushcutters Bay with a sub-branch towards Double Bay. Reticulation of parts of Paddington and Woollahra drains to this branch sewer.

1899 to 1903.

Waverley and Bondi Branch, which joins the main Bondi sewer about three-quarters of a mile from Ben Buckler and runs southerly to Murray Street, thence westerly to Bronte Creek. Reticulation of the Ocean slopes of Bondi and Waverley drains into this branch sewer.

1900.

Riley Street Branch, which joins the main Bondi sewer at Liverpool and Riley Streets, extending along the latter street in a northerly direction intercepting part of the sewage formerly discharging into Woolloomooloo Bay.

The following large branch sewers off the main outfall sewer were constructed by the Board during the years indicated to enable additional areas to be reticulated.

1907-1909.

Point Piper Branch, which joins Main Outfall Sewer on eastern side of Double Bay Valley, extending northerly across New South Head Road, then north-easterly to the junction of Wunulla Road, and New South Head Road and serves the reticulated areas of the western slopes of Bellevue Hill and Point Piper.

1913-1916.

Rose Bay Eastern Slopes Sewer, which joins the main outfall in Military Road, extending thence in a northerly direction crossing Murriverie and New South Head Roads to Dover Road and serves the reticulated areas of the Rose Bay slopes of Waverley, Woollahra and Vaucluse.

O'Sullivan Road Branch Sewer, which joins the main outfall near the junction of O'Sullivan Road and Old South Head Road, and extends thence in a north-westerly direction along O'Sullivan Road to near Beresford Crescent and Cranbrook Road. This sewer drains the reticulated areas of the Eastern slopes of Bellevue Hill.

North Bondi Branch, which joins the main outfall sewer about 18 chains from the outlet and extends in a southerly direction to serve the high land on Ben Buckler and provide an outlet for the North Bondi Low Level System.

Low Level Sewerage System

It has been pointed out earlier that the Bondi Outfall Sewer and main branches, constructed by the Government between the years 1880 and 1889 to intercept the old City sewers draining into the Harbour, could not take in areas below its gravitatable limit, and the sewage from these lower levels continued to go to the harbour outlets. To intercept this low level sewage and convey it into the Bondi Outfall Sewer, the Government later constructed pumping stations at different points as close to the foreshores of the harbour as possible. Connecting sewers were laid to each pumping station well, into which the sewage from the relative low level area is received. Rising mains, laid from the pumping stations to the gravitation intercepting sewer, enable the sewage to be pumped to the required levels.

Double Bay Low Level Area—In this area, comprising about 80 acres of the low lying ground at Double Bay and its foreshores, the first low level system in connection with the Northern or Bondi Outfall was installed by the Public Works Department and transferred to this Board in 1898. The installation consisted of Shone ejectors and an electric motor driven air compressing plant. There were originally three ejector stations located at different points in the area, and two were subsequently added by the Board, making five in all. The air compressing station

was situated on a triangular block of land at Short Street (formerly Gum Tree Lane), Olinda Lane and Goldman Lane, between New South Head Road and the foreshores of Double Bay. The sewage collected in the cast iron cylindrical chambers at the ejector stations was propelled into the gravitation sewers by the several ejectors operated by the compressed air delivered to each station from the compressing plant. These ejector stations remained in operation until 1929, when they were superseded by three of the Board's standard pumping stations. The site of the compressor station was sold in 1931 to the Double Bay Branch of the Boy Scouts' Association.

Low Level Pumping Stations—City and Suburbs. The original general installation of low level pumping stations to deal with the sewage from levels below that intercepted from the Harbour outfalls by the gravitation sewers of the Northern (Bondi Outfall) system, was completed by the Public Works Department and transferred to this Board in 1904. This consisted of a controlling station and 18 pumping stations. The later development of the low level sewerage system and the construction of the necessary additional pumping stations has been carried out by the Board, together with the necessary sewers to connect the low level reticulation system of each area with the relative pumping station, and the rising mains through which the sewage is pumped into the gravitation system.

Electrical Controlling Station. When the original 18 pumping stations of the Northern system were being constructed prior to 1904, and it was decided to adopt electric motor drive, electricity of the required voltage was only available for 16 of them from the Tramway power house at William Henry Street, Ultimo; the remaining two, being convenient to the Rushcutters Bay power house, were supplied with electrical energy from that service and had their own automatic control system installed. The electricity supply for 16 stations was therefore conducted to a central controlling station erected opposite the Ultimo tramway power house, from which it was distributed to the various pumping stations. The switchboard at the controlling station was divided into panels corresponding with each station on which were mounted the station ammeter, automatic circuit breaker, well indicator and motor starter. When the sewage reached top water level in the well at any of the pumping stations, a float working in a vertical pipe column in the well actuated a switch, which caused a signal to be sent to the controlling station showing "full" on the indicator. The attendant then operated the switch which started up the motors, and these continued to run until low water level was reached, when another signal was sent to the controlling station signifying "empty" on the indicator. The motor was then stopped, remaining so until the well was again full. The starting and stopping of the pumps being thus under the control of one man at

the controlling station, it was only necessary for oilers, who were each allotted a group of stations, to pay daily visits to inspect and oil the machinery.

Pumping Stations. The pumps originally installed were of the plunger type but these proved unsatisfactory from the beginning; breakdowns were frequent, resulting in the flooding of the stations and damage to the motors. The plungers were subject to rapid deterioration due to the sand and other gritty material carried in the sewage. By 1910 the whole of the plunger pumps had been replaced by centrifugal pumps, a satisfactory locally manufactured pump of this type having been obtained after a series of trials. As the sewage contains all sorts of foreign matter, the design of the pump adopted provided for large waterways through the impellers, and to prevent the destruction of the impeller blades and the pump casing by erosion, these surfaces were fitted with renewable cast iron liners.

The earlier pumping stations were constructed with rectangular underground chambers, lined with concrete where the excavation was in rock. A dividing wall separated the machinery chamber from the sewage collecting chamber. In other cases the underground chambers are elliptical, lined with flanged cast iron plates bolted together. Dividing walls are erected across each end of the ellipse, the end sections being the sewage wells, and the centre the machinery chamber. Pumping stations constructed in later years consist of two concentric concrete cylinders, the annular space between the two cylinders being divided and utilised for the sewage wells while the central space contains the machinery. Any seepage through the outer walls enters the collecting chamber or sewage well, and is pumped out with the sewage, thus maintaining a drier machinery chamber. Brick superstructures, of a design suitable to the locality, are erected over the underground chambers where the pumping stations are on Board's land, or in parks or reserves. Where they are in roadways or in reserves and a superstructure is not desired, hinged cast iron manholes at road or ground level form the means of access.

As the electricity mains had meanwhile been extended throughout the City and the near suburbs, pumping stations constructed by the Board since the original installation of 18 stations was completed by the Government in 1904 were connected to the street electricity mains at convenient points, and each station was provided with its own automatic control system. This consists of duplicate automatic motor starters installed in each station operated by float switch, obviating long cable connections with the Ultimo controlling station. This automatic control has become standardised, and the original group having been converted, the central controlling station has ceased to function in this regard for more than 20 years past.

LIST OF LOW LEVEL PUMPING STATIONS

Year Constructed	Station No.	Location	Low Level Areas Served
Original group constructed by the Government and transferred to the Board in 1904.	No. 1	Corner of Pyrmont and William Henry Streets, Ultimo.	Head of Darling Harbour as far as Belmore Park.
	No. 2	Corner of Wattle Street and Pyrmont Bridge Road, City.	Glebe (Blackwattle Bay Slopes), Blackfriars and George Street West Syphon.
	No. 4	Rose Street, Annandale, on west side of Johnston's Creek.	Glebe and Annandale, adjacent to Johnston's Creek.
	No. 5	Hutchinson Street, Annandale, near White's Creek.	Glebe and Annandale, adjacent to White's Creek.
	No. 6	Easton Park, Balmain.	Leichhardt and Balmain at the head of Rozelle Bay.
	No. 7	Mullens and Roberts Streets, Balmain.	Waterfront around White's Bay.
	No. 8	Reynolds Street, Balmain, near Buchanan Street (underground).	Balmain between Mansfield and Booth Streets.
	No. 9	Stephen Street, Balmain, near Wharf (underground).	Balmain, from Booth Street, easterly to Peacocks Point, thence northerly to Simmons Point, thence southerly to Waterview Street.
	No. 10	Mort Street, Balmain.	Balmain, areas formerly draining to Waterview Bay from Waterview Street, to Ballast Point.
	No. 11	Birchgrove Park, Balmain.	Balmain—Foreshores of Parramatta River from Ballast Point to Cove Street.
	No. 12	Washington Street, City.	Low lying area between Liverpool and Market streets, City.
	No. 13	Sussex Street, City.	Low lying area from Market Street northerly along Wharf frontages.
	No. 14	Crescent Road, Millers Point, City.	Low lying area between Millers and Dawes Points.
	No. 16	Barton Street, Circular Quay (underground).	Low lying area around Circular Quay.
	No. 17	Nicholson Street, City.	Low lying area around Woolloomoolo Bay.
	No. 18	Rushcutters Bay Park, City.	Low lying area in vicinity of Neilds Avenue, Paddington, and western foreshores of Rushcutters Bay.

	Year Constructed	Station No.	Location	Low Level Areas Served
Tr'fer'd from P.W.D., 1905		No. 19	Foot of Ithaca Road, Elizabeth Bay, City (underground).	Low lying area between Elizabeth Bay Road and eastern slopes of Potts Point.
		No. 20	Near John Street, Pyrmont.	Low lying area south western slopes of Pyrmont between Murray and Harris Streets.
Constructed by the Board.	1907	No. 23	Reserve near Beach Road, Rushcutters Bay (underground).	Eastern foreshores of Rushcutters Bay in Woollahra.
	1931	No. 25	Spring Street off William Street, Double Bay.	Ocean Street, etc., Double Bay.
	1914	No. 27	Callan Park Asylum Grounds, Balmain.	Adjacent low lying areas in Leichhardt and Balmain.
	1916	No. 28	Foot of Elliott Street, Balmain (underground).	Low lying areas in Balmain around Fig Tree Point.
	1918	No. 44	George Street West, opposite Buckland Street.	Pumps silt out of the George Street West syphon into the main sewer at Balfour Street, City. This silt was originally dealt with at No. 2 Station.
	1923	No. 46	Collins Avenue, Rose Bay.	Foreshores of Rose Bay from Lyne Park to Towns Road.
	„	No. 47	Rose Bay Park.	Foreshores of Point Piper and Rose Bay to Beresford Road.
	„	No. 48	O'Sullivan Road, Rose Bay.	Foreshores of Rose Bay, Beresford Road and Woollahra Park to Lyne Park.
	1924	No. 52	Botanic Gardens.	Farm Cove and Botanic Gardens.
	1927	No. 55	North Bondi Beach, Waverley.	North Bondi to Ben Buckler.
	1925	No. 56	Bronte Park, Waverley.	Bronte Beach (south) and Park.
	„	No. 59	Hickson Road, City.	Darling Harbour to Observatory Park.
	1927	No. 71	Glebe Island.	Glebe Island.
	1929	No. 87	Jamberoo Lane, off William Street, Double Bay.	Double Bay to Wallaroy Crescent.
	1930	No. 88	Kiaora Road, Double Bay.	Manning Road, Wallaroy Crescent, etc.

NORTHERN (BONDI) OUTFALL LOW LEVEL SEWERAGE SYSTEM

Year	No. of Pumping Stations	No. of Houses drained	Approx. Population served
1904	16	11,628	58,000
1914	20	13,350	66,000
1924	26	14,170	70,000
1928	33	13,393*	66,000

* Reduction due to demolitions in hitherto residential portions of the City and Glebe and their transformation into factory or business areas, one building superseding several terrace houses and so on.

The population figures given above are on a residential basis and take no account of the large accession of people to the City during business hours.

REFERENCES

Sewage and Health Board's report of 11th May, 1877.
Report on the interception of the drainage of the City of Sydney and Suburbs. W. Clark, M.Inst.C.E., 1876-1877.

CHAPTER XXI

SOUTHERN (BOTANY BAY SEWAGE FARM OUTFALL) SYSTEM

The main works of the Southern System, as formulated by the Sewage and Health Board in 1877, were constructed by the Government at the same time as those of the Northern System, viz., between 1880 and 1889, and were transferred to the Board by proclamation dated the 14th January, 1890.

There was no ocean outfall provided in the Southern Sewerage System as originally designed and constructed, its outfall being to a sewage farm. The area originally resumed by the Government for disposal of the sewage was 309 acres known as Webbs Grant, being a tongue shaped piece of land at the entrance to Cooks River, bounded on the north by that river and on the south by Botany Bay. The date of resumption was 11th August, 1882. The formation of this area consisted of raw drift sand originally covered with dense scrub. For agricultural purposes it was stated the soil was useless, but as a filter for crude sewage —this being the state in which the sewage was to be distributed over it —it could not be surpassed. When the Western Suburbs Sewerage Scheme was later commenced, an additional area of 311 acres, making 620 acres in all, was resumed to the west and south of the original area on 29th July, 1890. This additional land was mostly of a swampy nature and very little of it was ever utilised for filtering the sewage. It was used mostly for agistment of stock and in this way produced a revenue of from £300 to £400 per annum. About 30 acres were leased to Chinese market gardeners. The Botany end of the farm, to the extent originally of about 34 acres, was laid out in irrigation beds at different levels separated by earthen banks. Filtration drains about 4-feet deep were laid on the herringbone principle to convey the filtered effluent to Cooks River. The beds were flooded in rotation, and on those not in use the sludge was deposited and ploughed in and the beds cultivated.

The procedure was as follows:—The sewage passed from the main sewer into the screening chambers of the inlet house situated on the northern bank of Cooks River near the entrance. These chambers were in duplicate and controlled by valves, so that when one series was in use the other was being cleaned out. The sewage was screened before passing into the syphon well. Lime was used to some extent for precipita-

tion and cleansing purposes. Until about 1903 the sludge was grabbed out of the wells, and conveyed in wrought iron side tipping trucks drawn by a steam locomotive along a line of rails laid across a timber bridge over Cooks River to the filter beds, where it was drained and ploughed in. In the year mentioned, the timber bridge had reached the end of its useful life, and a submarine ball and socket pipe line was therefore laid across Cooks River and two ejectors with air compressing plant, consisting of two combined oil engines and air compressors were installed at the inlet house to force the sludge across the river. It was then put into trucks and drawn by the locomotive to the filter beds. The screened sewage passed from the syphon well in the inlet house under the bed of Cooks River by a cast iron inverted syphon, 3 feet 9 inches in diameter, to a well in the outlet house on the south side of the river, whence it flowed along a concrete surface carrier for distribution to the filter bed areas. In the early years the average daily discharge of sewage on the farm was 1,450,385 gallons in midsummer, and in midwinter 1,576,877 gallons from a drainage area of 1,079 acres.

During the first year the farm was under the Board's control it produced from the $4\frac{3}{4}$ acres cultivated, 23,500 cabbages, 11 tons of turnips, 39 tons of lucerne and 6 tons of sorgham. The total proceeds from the crops amounted to £198 0s. 1d. The following year the proceeds of sale of crops amounted to £300 6s. 11d. In the farm manager's report for 1891 it is recorded that, owing to the quantity of crops not disposed of and the refuse from crops sold, 16 head of dry cows, one bull and six pigs were purchased to consume this surplus fodder. Styes constructed in concrete were provided for the pigs and suitable sheds and stalls for the cows. It is further recorded that during the year 11 calves were born. This formed the genesis of stock-raising activities on the farm, which were continued with satisfactory results for some years. Areas not suitable for crop raising were laid out in grass paddocks and agistment of stock became an appreciable source of income.

In 1893 the Board decided that, having shown what could be done with the farm in a commercial way, it would be sound policy to lease it for a term of years. The farm was accordingly leased in 1894 for ten years, at a rental of £200 per annum, subject to conditions necessary to enable the Board to continue the use of the land for disposal of sewage. This action, it was stated, would result in the disposal of sewage costing the Board nothing, whereas an annual loss of between £500 and £600 occurred in the working of the farm—the rental covered supervision, etc. The experiment of leasing was not a success. The farm was not properly maintained by the lessee, and the Board's operations in the disposal of sewage were so prejudiced that it was compelled to cancel the lease at the end of about twelve months. By 1896, the average daily flow had increased by 50 per cent to 2,361,000 gallons, and the

area of filter beds from 34 to 65½ acres. The ploughing and harrowing of the beds was carried out by annual contract. The use of lime for precipitation purposes at the inlet house had been discontinued except for cleansing purposes, but it was found that absence of lime in the sludge was affecting the growth of crops and its use for partial precipitation was renewed. Meanwhile the outfall for the Western Suburbs Sewerage Scheme was approaching completion, and the area of the farm was increased by resumption from 309 acres to 620 acres as previously stated, the additional area, being to the west of Webbs Grant, was known as the Rockdale or Arncliffe Sewage Farm. It was taken over by the Board from the Government (Public Works Department) in 1897. The average daily flow on this area from the Western suburbs during the first twelve months was 1,750,000 gallons. The area laid out in filter beds for the Southern system had been increased in 1903 to 71 acres, that for the accommodation of the sewage from the Western suburbs being 96 acres.

In 1898 the light railway line was extended from the Botany to the Rockdale end of the farm to facilitate working.

In 1899 the Board erected at the farm five workmen's cottages of brick with tiled roofs to neat design, and these cottages are still in evidence on the area which now belongs to the North Brighton Suburb Estate Co. Ltd. A weatherboard cottage occupied by the manager at the Botany end of the farm was taken over by the Board from the Government with the original works in 1889. It was later enlarged by adding a suitable room for the Board to meet in when visiting the farm. This cottage is still standing, and is used in connection with the North Brighton Golf Links, which forms part of the area sold in 1929 to the North Brighton Suburbs Estate Company Ltd.

In 1900 six imported pedigree pigs were purchased from the Agricultural College, pig raising being by this time an important phase of operations at the farm.

The average daily flow from the Southern system to the farm had increased from 2,361,000 gallons in 1896 to 3,250,000 gallons in 1900.

In view of complaints from residential localities adjacent to the farm alleging a nuisance, and threats of legal action, the Board, for experimental purposes, put in a small installation in 1898 of filters and tanks on the Scott-Moncrieff principle, with a view to ascertaining the feasibility of changing to the biological treatment of the sewage in lieu of the then existing system. In 1905 complaints of nuisance arising from the operation of the sewage farm had become so general on the part of residents of Rockdale and the local councils, that a proposal for the treatment of the sewage from the Western suburbs by liquefying tanks and filters installed at the Western outfall at the farm was referred to the Parliamentary Standing Committee on Public Works. The Com-

mittee after investigation and the taking of evidence as to nuisance, etc., submitted a recommendation dated 28th November, 1905, that the work be carried out. About twelve months later, however, a scheme of sewerage for portion of the Illawarra suburbs was referred to the Public Works Committee for investigation. The Committee after due investigation passed the following resolution in November, 1906:—

> "That in the opinion of the Committee it is expedient the proposed Scheme of Sewerage for the Illawarra Suburbs as referred to them by the Legislative Assembly, be carried out, *with the exception of constructing works for the disposal of the sewage*, the postponement of that part of the scheme being advisable in order to await the result of inquiries with reference to extending the Western Suburbs Outfall to Long Bay or its vicinity."

In 1905 the industry of pig raising on the farm, which had been developed on a remunerative basis, met with disaster due to an outbreak of swine fever. Acting on the advice of the Board's Medical Officer and the Veterinary Surgeon of the Board of Health, the infected pigs were destroyed and the balance killed or disposed of. Pig raising was not again taken up on the farm. By 1908 the raising of crops had diminished to very small proportions as the increased average daily flow of sewage, which was now 3 million gallons from the Southern system and $3\frac{3}{4}$ millions from the Western system, kept the cultivation areas almost continuously flooded. The complete abandonment of this activity became necessary a few years later.

In 1916 the Southern and Western Suburbs Ocean Outfall Sewer, which had been constructed to convey to the ocean the sewage hitherto discharged on to the sewage farm, was completed. On the 21st August, 1916, the Western main sewer was connected to the S. & W.S.O.O. Sewer, and on 14th September, 1916, the Southern main sewer was connected. From the latter date the sewage farm ceased to operate. The cottages formerly occupied by employees were vacated and let to non-employees. In 1918, an attempt was made to lease out the filter bed areas in lots of from 5 to 8 acres for market gardening, but without success, as analysis of the soil showed that it had quickly gone back to raw sand notwithstanding years of flooding with raw sewage. Eventually the whole of the sewage farm land, excepting about 45 acres retained to accommodate the main sewers passing through the land, was disposed of as follows:—

Acres	roods	perches		
215	3	24	Sold to	North Brighton Suburb Estate Co. Ltd.
56	1	$1\frac{1}{2}$	„ „	New South Wales Polo Association ("Kyeemagh").
29	2	$8\frac{1}{2}$	„ „	New South Wales Cricket Association.
61	3	22	„ „	W. C. Allen.

Acres	roods	perches	
88	2	0	Sold to Lands Department for park purposes, being the land between General Holmes Drive and the Shores of Botany Bay.
79	0	0	„ „ Rockdale Municipal Council and Lands Department for park purposes.
19	1	22	Dedicated for road purposes (General Holmes Drive and Marsh Street).
550	1	37¾	
43	1	10	Leased to Rockdale Council.
593	3	7¾	

The total proceeds of the sales amounted to .. £45,323 11 11
The original cost of the whole area was £37,985 13 8

The original main and branch sewers of the Southern system completed by the Government and transferred to the Board in December, 1889, may be described as follows:—

The Southern Main Outfall Sewer commenced at the inlet chamber on the north bank of Cooks River near its junction with Botany Bay. The sewer is 5-feet 6-inches in diameter constructed of concrete with brick lining cement rendered. Between the inlet house and Botany Road the sewer for the most part is in embankment, and passes through low sand hills and swampy ground. Where natural watercourses are crossed, concrete culverts, overflow chambers and valves are provided. At Botany Road the size of the sewer is decreased to 5-feet 6-inches by 3-feet 6-inches. From Botany Road the sewer extends along Bourke Street through the boroughs of Waterloo and Redfern to Phelps Street, Surry Hills. It drains the southern watershed of the City, Redfern, Waterloo, Alexandria, MacDonaldtown and Newtown.

MacDonaldtown and Alexandria Main Branch (Transferred to Board 1892). This main branch joins the outfall sewer at a point a little over two miles from the inlet house at Cooks River, and is constructed in cast iron and wrought iron 30-inch pipes along Harley Street to Mitchell Road and Reserve Street. It is carried in aqueduct over low lying ground at Alexandria, and receives the sewage from portions of Alexandria, Erskineville and Newtown.

Low Level Sewerage

Alexandria Ejector Station. This ejector station was installed in 1894 to serve a district in Alexandria which was too low to admit of it being drained by gravitation, and had a very high death rate from enteric fever. The sewage was lifted into the gravitation system by Shone ejec-

tors similar to those installed at Double Bay low level area. The ejectors were operated by an air compression plant. The station ceased to operate in 1897, when the Marrickville low level steam pumping station was completed and dealt with the sewage from this area. The Alexandria ejector station was dismantled in 1900 and the plant sold.

The following are the electrical pumping stations (automatically controlled) constructed by the Board in the years indicated, operating in connection with the sewerage of the low levels of the Southern sewerage system. The function of these pumping stations is to pump the sewage which flows into the receiving chambers from the low level reticulation into the most convenient submain of the gravitation system to the outfall:—

Year Constructed	Station No.	Location	Low Level Area Served
1925	39	Huntley Street, Alexandria.	Vicinity of Alexandra Canal and Alexandria Park.
1924	53	Coward Street, near Botany Road, Mascot.	Mascot Park, etc.

The number of houses drained to these pumping stations is 1,500. Approximate population served 6,500.

REFERENCES

Sewage and Health Board's report of 11th May, 1877.
Report on the interception of the drainage of the City of Sydney and Suburbs. W. Clark, M.Inst.C.E., 1876-1877.

CHAPTER XXII

WESTERN AND ILLAWARRA SUBURBS (ROCKDALE SEWAGE FARM OUTFALL) SYSTEM

The original Western Suburbs Sewerage Scheme was drawn up in 1888 by Mr G. H. Stayton, M.Inst.C.E., who is referred to in the report of the Parliamentary Standing Committee on Public Works dated 27th August, 1889, as an engineer of considerable English experience, who for some years was connected with the Sewerage Branch of the Department of Roads and Bridges. The scheme was concurred in by Mr W. C. Bennett, M.Inst.C.E., who at the time was Commissioner and Engineer-in-Chief for Roads, Bridges and Sewers, and one of the official members of the then newly created Board of Water Supply and Sewerage.

The construction of the main works of the scheme was carried out by the Public Works Department, and they were transferred to the Board as completed in sections between 1898 and 1900.

Outfall. Until 1916, when the Southern and Western Suburbs Ocean Outfall Sewer to Long Bay was completed, the sewage from the Western suburbs was dischargd at the western side of the sewage farm, an additional area of 311 acres referred to in Chapter XXI having been resumed to the west and south of the original sewage farm area of 309 acres used in connection with the Southern System Outfall.

Main Outfall Sewer. The main outfall sewer extended from a screening chamber at the Rockdale end of the sewage farm in carrier 5-ft. 3-in. by 8-ft. 8-in. to another screening chamber about half a mile to the south-east. This carrier was later raised to 6-ft. 3-ins. in height. From the screening chamber first referred to it continued as a 6-ft. circular triplicate sewer in tunnel and in aqueduct over low lying ground and in duplicate 6-ft. circular steel barrels over Wolli Creek and Cook's River to a penstock chamber in Premier Street, Marrickville.

Over the Premier Street penstock chamber a lofty ventilating shaft was erected. This penstock chamber receives the discharges of three main branch sewers. In 1927, a third 6-ft. circular steel barrel was constructed by the Board where the outfall sewer previously crossed Cook's River and Wolli Creek in duplicate barrels. A large junction chamber with seven 72-inch penstocks controlling the ingress and egress of the

flow of all barrels was also constructed at Wolli Creek. The outer barrels of the carrier at one point in Arncliffe were also re-constructed in reinforced concrete.

Original Main and Branch Sewers

Eastern Main Branch—Extends from the penstock chamber at Premier Street along Illawarra Road northerly, partly in syphon where it crosses a valley, to Stanmore Road, thence northerly across the Main Suburban railway line and Parramatta Road to Collins Street, Annandale. The area reticulated to this branch and its submains includes portions of Marrickville, Newtown, Petersham, Leichhardt, Annandale, and Camperdown.

Northern Main Branch—Extends from the Premier Street penstock chamber northerly, passing under the Belmore railway line near Livingstone Road, thence along Wardell Road through Petersham, crossing the Main Suburban railway near Lewisham station, through Leichhardt, passing along Flood, James and Church Streets, terminating at the latter street. The area reticulated to this main branch and its submains includes portions of Marrickville, Petersham, Annandale, Leichhardt and Ashfield.

Western Main Branch—Extends from the Premier Street penstock chamber north-westerly through Marrickville, crossing the Belmore railway near Dulwich Hill station, thence through Ashfield crossing the Main Suburban railway near Croydon station; thence through Burwood, passing along George Street to Park Road and westerly again crossing the railway between Burwood and Strathfield stations to and along Morwick Street and Margaret Street across Redmyre Road to Albert Road. The area reticulated to this main branch and its submains includes portions of Marrickville, Petersham, Ashfield, Burwood, Drummoyne, Strathfield, Concord and Homebush.

In October, 1926, it was found the gases from the Abattoir wastes had caused damage to the main Western sewer to such an extent that repairs could no longer be delayed.

Investigation disclosed that for a distance approximately of one mile downstream from where the Abattoir sewage entered the main sewer, considerable softening of the concrete used in the roof and walls of this sewer above the flow line had taken place. Similar softening of the concrete was also in evidence in the pump wells at Homebush Pumping Station, which received the sewage from the Abattoirs and pumped it into the main sewer.

The cost of re-conditioning the main sewer and the pumping station wells amounted to nearly £8,000, and the Board made a claim against

the Metropolitan Meat Industry Board for recoupment of this amount. The latter body not admitting liability, the matter was referred to the Minister for Public Works in terms of Section 146 of the Board's Act for settlement by the Governor, this being the procedure laid down in that section of the Act in the case of a dispute arising between the Board and any Government department or other statutory body.

The Commissioner appointed to investigate the dispute, in his report, stated that the evidence appeared to him to strongly support the view taken by the Water Board that the damage to the sewer arose solely or almost solely from the action of sulphuretted hydrogen gas emitted by the wastes from the Abattoirs. He also stated that the presence of this gas first became apparent through odours arising from the sewer vents, and by reason of insistent demands by the public that this should be remedied the Water Board was forced to close the vents, thus accentuating the softening of the concrete or of running the risk of legal proceedings and the issue of an injunction against it to abate the nuisance.

The Commissioner's finding, however, was indeterminate, as it did not place the responsibility for meeting the cost of the repairs upon the Meat Board, but suggested that the Government might consider reducing the Water Board's capital indebtedness to the State by the amount in question. This course the Government was not prepared to agree to, one reason being that the expenditure incurred in carrying out the repairs was not capital expenditure.

The Commissioner held, in effect, that the Abattoirs sewerage scheme was carried out by the Board under an arrangement with the Meat Industry Board whereby the latter was to pay for the service on a special basis, and there was no condition expressed or implied in that agreement that the Meat Board should render the wastes innocuous or reimburse the Board for any damage to the sewers caused by such wastes. He further expressed the view that the Meat Board had made an earnest endeavour to ameliorate the conditions complained of.

The following main branch sewers were constructed in subsequent years:—

Canterbury-Enfield Branch.—Joins the Main Western branch near Wardell Road, Marrickville, and extends thence generally in a westerly and north-westerly direction crossing the railway at Hurlstone Park, crossing the western part of Canterbury Park and following the north side of the Cook's River Valley to just beyond Enfield. The area reticulated to this branch comprises the southern parts of Ashfield, Burwood, and Strathfield, also parts of Enfield and Canterbury. The main portion of this branch sewer was constructed by the Public Works Depart-

ment in sections between 1910 and 1916, and transferred to the Board in 1913 and 1918. The portion between Dean Street, Enfield, and Homebush Road, Strathfield, was constructed by the Board, part in 1924 and part in 1928.

Illawarra Suburbs Branch Eastern Division.—Joins the Main Western Carrier near Eve Street, Arncliffe, and extends in a southerly direction following close to Princes Highway, which it crosses in Rockdale terminating at Muddy Creek, where it bifurcates into two branches—Kogarah Road and Gladstone Street Submains. It was constructed by the Board under four separate contracts between 1906 and 1909. The main branch sewer with its submains provides for the reticulation of portions of Rockdale, Bexley and the north-eastern portion of Kogarah adjacent to the Illawarra railway line.

Illawarra Suburbs Branch Western Division (Bardwell Creek).—Joins the Main Western Carrier at Bonar Street, Arncliffe, and extends generally in a south-westerly direction to the end near Romani Avenue, Hurstville. It was constructed by the Board under four separate contracts during 1927 and 1928. This main branch provides for the reticulation of the northern portions of Rockdale and Bexley and the shopping centre at Hurstville.

Canterbury-Campsie-Belmore-Bankstown Branch—Joins the Main Western Carrier at the Wolli Creek junction chamber near Unwin Street, Undercliffe, and extends generally in a westerly direction terminating at Chullora Workshops. It was constructed by the Public Works Department in 1927 and transferred to the Board in August, 1928. The branch with its submains (Wolli Creek, Cup and Saucer Creek and Belmore) provides for the reticulation of the Cook's River and the Wolli Creek Valleys, which include the main portion of Canterbury and parts of Rockdale, Bexley, Hurstville, Enfield, Bankstown, Strathfield and Lidcombe.

Low Level Sewerage—Steam Pumping Stations

Marrickville:

The low-lying portions of Marrickville, Newtown, Erskineville, Alexandria, and practically the whole of St. Peters are served by low level sewers discharging into the wells of the pumping station established at Meeks Road, Marrickville, south of the Bankstown railway. This station also receives, under certain tidal conditions in Cook's River, the stormwater discharge from the central stormwater channel draining portion of Marrickville Valley. This channel is one of three draining this valley. The other two, known as the eastern and western, discharge

by gravitation into Cook's River, but the central channel, which drains the lower levels, has its outlet at low water level at Cook's River where a self-acting sluice gate excludes tidal waters. When the tide rises and the outlet closes, the stormwater discharges into the pump wells at the Marrickville station and has to be pumped from there into the eastern stormwater channel. The pumping station was constructed by the Public Works Department and taken over by the Board's staff in March, 1900. It was formally transferred in 1902. The pumping plant consists of:—

For Sewage—	Two Hathorn Davey steam pumps—Capacity 5,660 gallons per minute. Three Cornish boilers and one Babcock and Wilcox boiler.			
For Stormwater—	1 Diesel plant—	Capacity	10,000	gals. per min.
	1 33" electrical centrifugal pump	"	15,100	" "
	2 21" do.	"	12,600	" "
	Total		37,700	

Originally the stormwater plant consisted of a Raworth high speed engine, direct coupled to a Gwynne centrifugal pump and this was added to in 1904 by the transfer from Prospect Pumping Station (erected during the drought of 1902) of two 16-inch Robinson centrifugal pumps. This plant was superseded some years back.

Homebush:

This station was constructed by the Public Works Department and transferred to the Board with the relative low level sewers in 1903. It was situated near Powells Creek and Homebush Creek, north of Parramatta Road, and was equipped with steam pumping plant. It served low level areas in Homebush, Concord, Strathfield and Burwood adjacent to Powells Creek. It was dismantled in 1914, being superseded by a new station, No. 41 and hereinafter referred to, which was erected adjacent to the Homebush Abattoirs in order to serve that establishment in addition to the area previously served. The whole of the low level sewers draining to the old station were connected to the new one.

Electric Pumping Stations

The following is a list of the electrical pumping stations (automatically controlled) operating in connection with the sewerage of the low levels of the Western Suburbs Sewerage System. The function of these pumping stations is to pump the sewage which flows into the receiving chamber from the low level reticulation into the most convenient submain of the gravitation system to the outfall.

Year Constructed	Station No.	Location	Low Level Area Served
Transferred from Public Works Dept. in 1904	3	Booth St., Annandale	Originally equipped with plunger pumps which were superseded a few years later by "Sands" centrifugal pumps installed by Board. Operated from Central Electrical Controlling Station, Ultimo, until 1913, when it was converted to automatic control with all other stations formerly operated by central control as explained under Northern System Sewerage. Serves low level areas Johnstone's Creek, Camperdown.
Transferred from Public Works Dept. in 1904	15	Hawthorne Pd., Ashfield	Originally equipped with Gwynne pumps with gas engine drive. Pumps replaced by Board's standard "Sands" centrifugal pumps. Converted to automatically controlled electrical drive in 1910, power being then available from tramway electric mains. Serves low level areas in Ashfield, Leichhardt and Petersham at the upper end of Long Cove Creek stormwater channel.
Transferred from Public Works Dept. in 1908	21	Athol St. and Darley Rd., Leichhardt	Originally operated by gas engine drive. Converted to automatically controlled electric drive in 1910. Serves low level areas in Ashfield and Leichhardt at the lower end of Long Cove Creek stormwater channel or Hawthorne canal.
Constructed by Board in 1908	22	St. Luke's Park, Concord	Concord and Burwood adjacent to St Luke's Park.
Transferred from Public Works Dept. in 1910	26	Martin St., Ashfield (Iron Cove Creek)	Drummoyne, Ashfield and Burwood adjacent to Iron Cove Creek stormwater channel.

Year Constructed	Station No.	Location	Low Level Area Served
Constructed by Board in 1915	29	Queen Victoria St., Drummoyne	Along the foreshores of Parramatta River from Perdriau's works to Drummoyne Wharf.
do. do.	30	Ullathorne St., Drummoyne	Along the foreshores of Long Cove from Sisters Crescent to Janet Street, Henley Marine Drive.
do. 1916	31	Third Av., Drummoyne	At head of Hen and Chicken Bay.
do. do.	41	Underwood Rd., Homebush	Superseded the old steam pumping station constructed by the Public Works Dept. and transferred to the Board in 1903. New station erected adjacent to State Abattoirs and Brickworks to serve these establishments as well as area served by original station adjacent to Powells Creek stormwater channel.
do. do.	42	Homebush Bay, Lidcombe	Serves low level areas adjacent to former State Brickworks delivering to No. 41 pumping station.
do. 1921	45	Wardell Rd., Cook's River, Marrickville	Adjacent to Cook's River, Dulwich Hill.
do. 1923	58	Westbourne St., Drummoyne	Adjacent to Drummoyne Park, Five Dock Point.
do. 1926	61	Hill St., Abbotsford	Adjacent to Hen and Chicken Bay and Five Dock Park.
do. 1929	62	St. Albans St., Abbotsford	Adjacent to Hen and Chicken Bay, Henry Lawson Av., to Battersea St.
do. 1934	63	Teviot Av., Abbotsford	Adjacent to Fig Tree Bay, Walton Cres. and Bay St.
do. 1937	65	Byrne Av., Drummoyne	Moore St., Coralie St., etc., Five Dock Bay.
do. 1929	66	Henley Marine Drive, Drummoyne	Iron Cove, Rodd Park, Five Dock Park, etc.
do. 1929	68	Wharf Rd., Cook's River, Marrickville	Riverside Park, Cook's River.

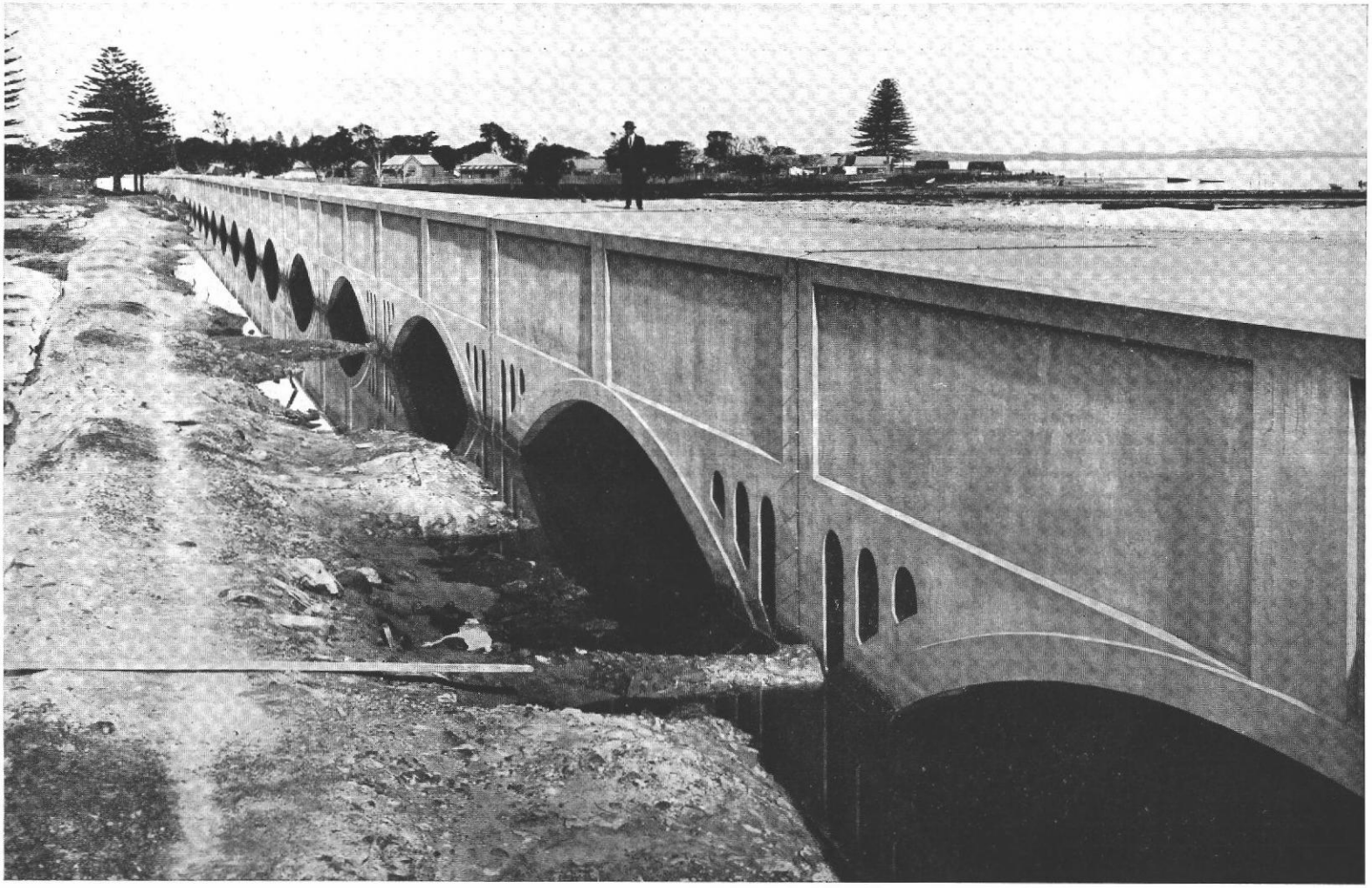
Year Constructed	Station No.	Location	Low Level Area Served
Constructed by Board in 1928	72	Wellbank St., Concord	Exile Bay.
do. 1930	78	Burton St., Rockdale	Princess St. and Bestic St., Brighton-le-Sands.
do. 1928	82	Church & Hulton Sts., Canterbury	Hurlstone Park South, Canterbury Park, Cook's River.
do. 1928	84	Brighton Av., Croydon Park	Cook's River, Croydon Park and Henley Park.
do. 1934	86	Punchbowl Rd., Cook's River, Canterbury	Punchbowl Rd., Cook's River.
do. 1931	89	Chapel St., Rockdale	Muddy Creek, Solander St., Brighton-le-Sands.
do. 1937	90	Nullawalla Av., Major Bay, Concord	Concord Golf Links, Yaralla Av., etc.
do. 1938	91	Near Victoria Av., Concord	Part of Concord.

WESTERN AND ILLAWARRA SUBURBS LOW LEVEL SEWERAGE SYSTEM

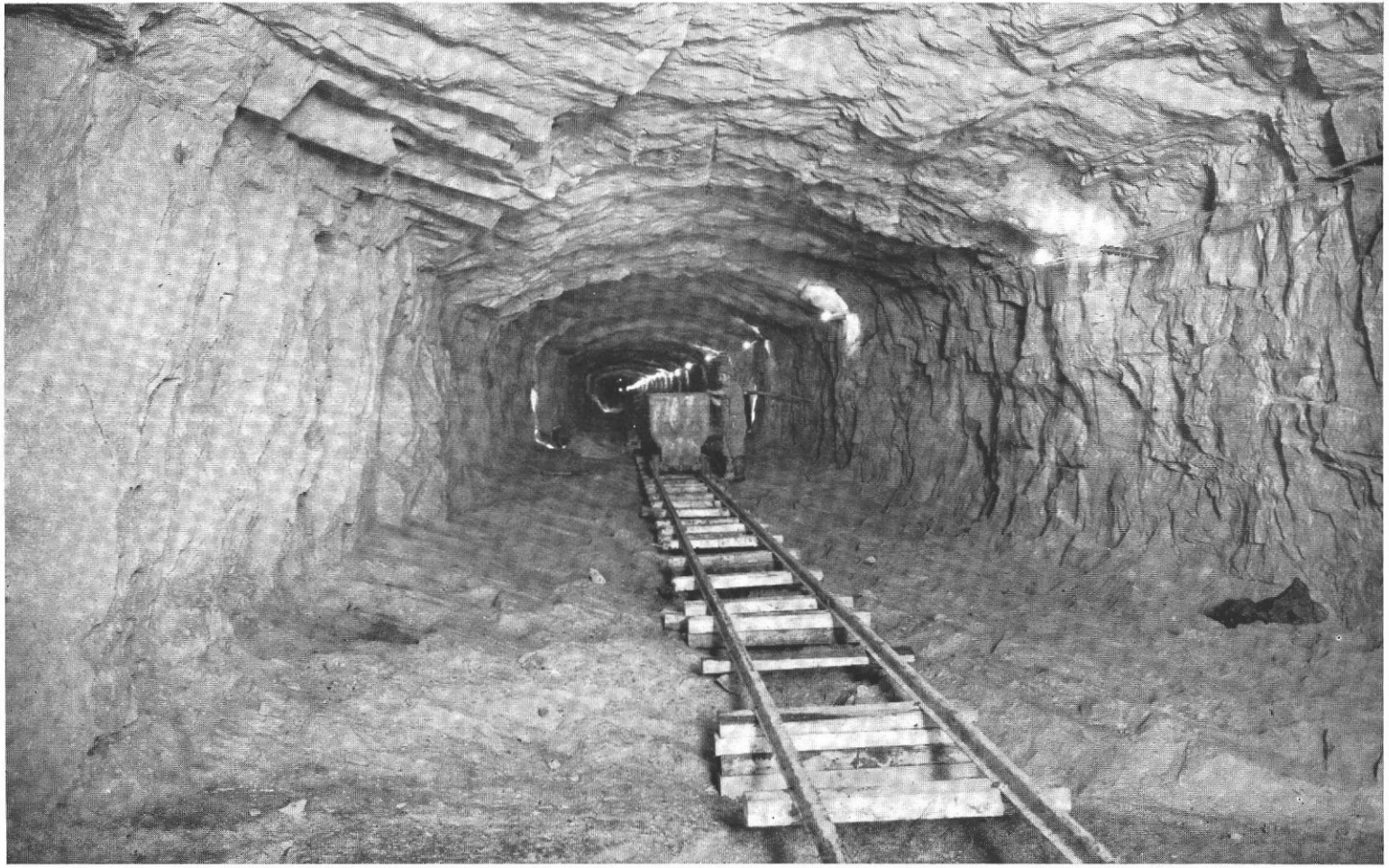
No. of Stations in operation	No. of houses drained	Approximate population served
1904 4	5,441	27,000
1914 6	11,207	55,000
1924 13	15,272	76,000
1938 27	27,585	119,000

REFERENCES

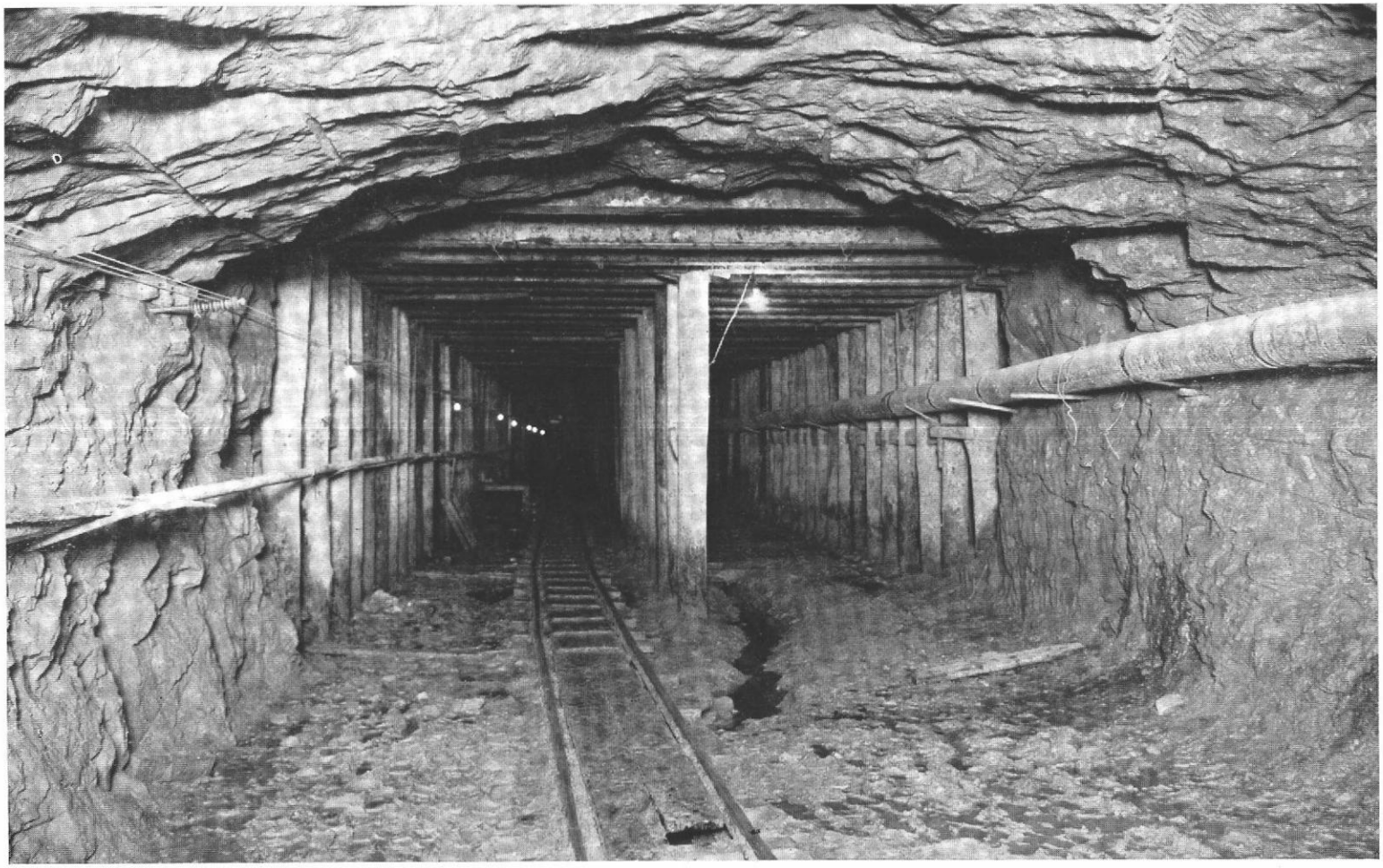
Report on the Sewerage and Drainage of the Western Suburbs. George H. Stayton, M.Inst.C.E., 1887-1888.
Parliamentary Standing Committee, 1889, 1890, 1900, 1905, 1906 and 1925.



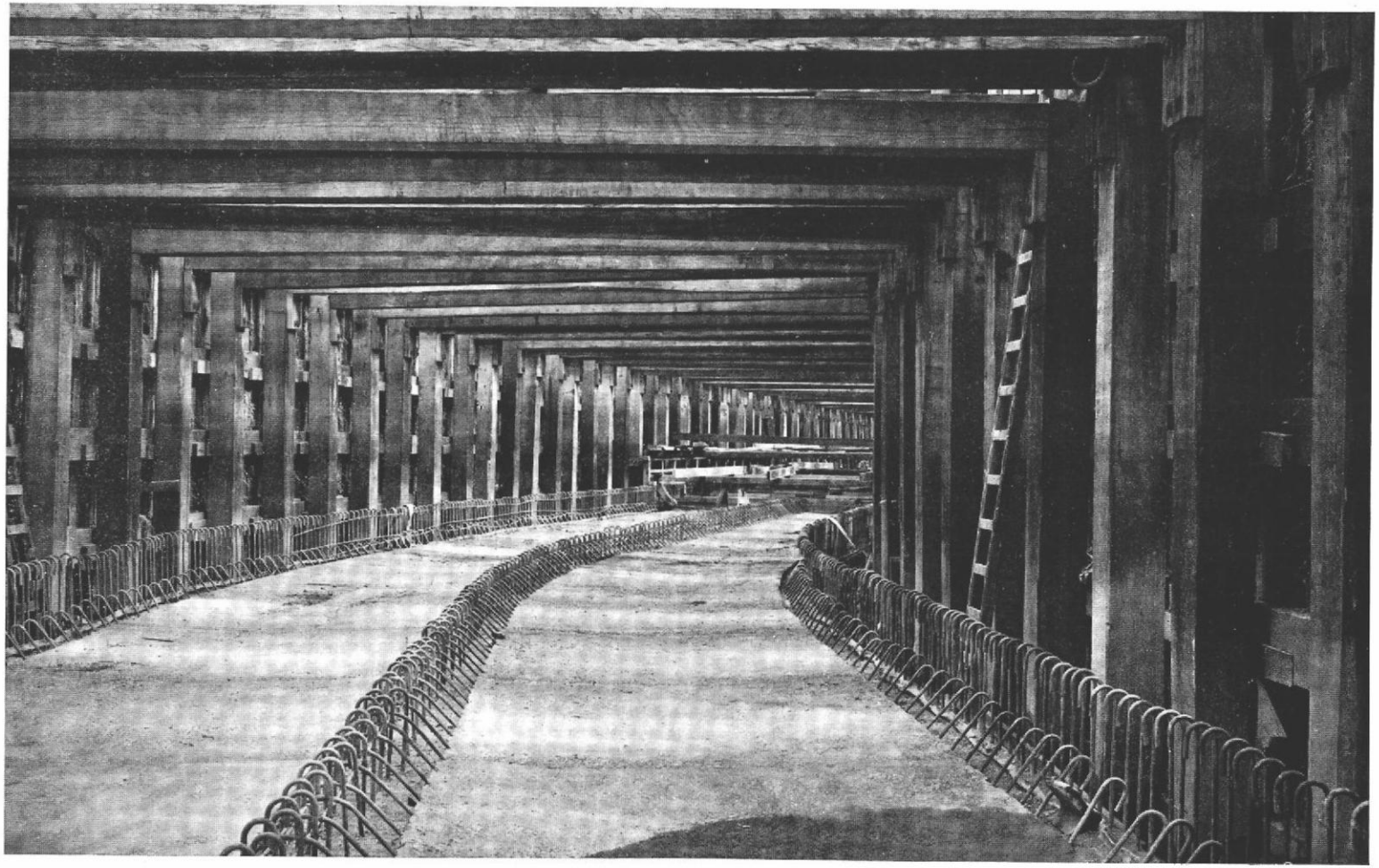
SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 1.
Aqueduct on the Arncliffe side of Cooks River.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 1.
Shafts 1 and 2. Tunnel completed ready for concreting.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 1.
Shaft 4. Timbered tunnel looking downstream. Size of tunnel 18′ x 10′.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 2.
Deep trench near Perry Street, showing invert concreted.

CHAPTER XXIII

SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER—FIRST PHASE

In the chapter dealing with the Southern Sewerage System and the operating of the Botany and Rockdale Sewage Farms, reference is made to investigations which were carried out in 1905 into a proposal to install septic tanks and filters for the treatment of the sewage owing to the complaints from the Council and residents of Rockdale, regarding nuisance arising from the sewage farm. This investigation was decided upon as being involved in the proposal then under review to bring the sewage from the Illawarra suburbs into the main Western Outfall at the farm. It is also there related that the Parliamentary Standing Committee on Public Works, after full enquiry, recommended that the Illawarra Suburbs Sewerage Scheme be carried out "but that the construction of the treatment works be postponed in order to await the result of enquiries with reference to extending the Western Suburbs Outfall to Long Bay or its vicinity."

In 1908 the Parliamentary Standing Committee on Public Works commenced an enquiry into two schemes to divert the sewage from the Southern, Western and Illawarra Suburbs from the sewage farm to the ocean near Long Bay. The Board submitted a partial pumping and gravitation scheme, while the Public Works Department submitted a gravitation scheme.

During the enquiry by the Public Works Committee, the Minister for Public Works, having regard to the fact that certain evidence had been given that a gravitation system might not operate effectively owing to the flat grade of the proposed sewer, referred the Public Works Department's scheme to a board of London experts. The experts' report favoured the gravitation proposal, subject to modifications which increased the grade from 1 in 4,430 or about 1 ft. 2½ inches per mile, to 1 in 3,650 or about 1 ft. 5¼ inches per mile. The Public Works Committee in December, 1908, recommended the construction of the gravitation sewer with the alteration in grade as recommended by the London experts, the soffit of the outfall discharge pipes to be 20 feet below high

water spring tides. The cost of the scheme was estimated not to exceed £452,400. The construction of this ocean outfall sewer (now known as the Southern and Western Suburbs Ocean Outfall Sewer No. 1, seeing that its duplication is in progress at the present time) was carried out by the Public Works Department under three separate contracts, and completed in 1916 and then put into commission, conveying to the sea the sewage previously discharged at the sewage farm near Cooks River. The sewer discharges through a bifurcated outlet to the ocean in a submerged cliff at the northern headland of Long Bay. The outlet legs are 5 feet in diameter and their common soffit level, at the points of discharge, is 25.73 feet below sewerage datum, which later approximates high water ordinary spring tides. The outlets are laid in rock tunnel at 1 in 15 to the outlet shaft, from which point the actual sewer construction commenced at invert R.L. −2·22, i.e. nearly 2¼ feet below high water mark. A common gradient of 1 in 3,650 was applied from the outlet shaft to the eastern side of Cooks River, which was crossed by twin syphon barrels, and from the western side of the river to the upstream end of the construction the applied gradient was 1 in 2,900. The construction terminated at a screening chamber being the downstream end of the Muddy Creek Carrier at the Rockdale end of the Sewage Farm where the flow from the Western and Illawarra Suburbs becomes intercepted. The construction details are as follows:—

(1) From footage 0.00 to 4,250 the sewer was constructed in rock tunnel finished in plain concrete to 7 feet 6 inches by 12 feet 3 inches, boat section, with semi-elliptical reinforced concrete arched roof of 1 foot 6 inches camber.

(2) From footage 4,250 to 4,820 the construction was trench in soft ground up to 45 feet deep, the finished size in plain concrete being 9 feet by 12 feet 3 inches, boat section, with semi-elliptical arched roof of 3 feet camber.

(3) From footage 4,820 to 5,575 the construction was similar to that indicated in (2), the only variation being the size, which was reduced to 9 feet by 12 feet.

(4) From footage 5,575 to 11,930 the construction was similar to that indicated in (1), the size only being altered to 7 feet 6 inches by 12 feet.

(5) From footage 11,930 to 21,000 the excavation was in sand trench at depths varying between 67 and 10 feet, some parts being heavily water-charged. The finished size was in reinforced concrete 10 feet by 11 feet 2 inches, placed on a reinforced concrete mattress, in boat section, with semi-elliptical arched roof of 4 feet camber.

(6) From footage 21,000 to 22,950 the excavation was in sand trench varying in depth from 12 to 0 feet, the sewer being constructed almost out of ground in places. The finished size was 6 feet by 11 feet 2 inches boat section, placed upon a reinforced concrete mattress. The sewer was in plain concrete as to part of walls and invert, while the rest of the walls and roof was reinforced the latter being flat in cross section.

(7) From footage 22,950 to 24,070 the finished size of sewer was 5 feet $11\frac{5}{8}$ inches by 11 feet 2 inches, construction in other respects being similar to that indicated in (6), save only that the mattress was cellular and rested on the natural surface, there being scarcely any excavation.

(8) From footage 24,070 to 25,230 the finished size was 5 feet $11\frac{5}{8}$ inches by 11 feet 2 inches, a transition in size taking place from 25,230 to 25,288, from which latter point the finished size became 5 feet $4\frac{5}{4}$ inches by 11 feet 2 inches and continued to 25,632·5. The sewer was constructed of reinforced concrete as to flat roof and walls, the invert being plain concrete. The sub-structure consisted of arches and piers, the sewer being wholly above ground.

(9) From footage 25,632·5 to 26,248·96 twin shafts, each 10 feet by 10 feet, segmental type, connected with twin barrels each 4 feet 3 inches in diameter, were designed as inverted syphons to carry the flow beneath Cook's River.

(10) From footage 26,248·96 to 26,825 the sewer in finished size, 5 feet 9 inches by 11 feet $4\frac{1}{2}$ inches, box section, in aqueduct, is carried on piers and arches. The flat roof and walls were of reinforced concrete while the invert was in plain concrete.

(11) From footage 26,825 to 30,450 the sewer being of similar cross-section to that in the preceding paragraph and there being only very shallow excavation, the substructure consists of a reinforced concrete mattress, cellular in places.

(12) From footage 30,450 to 31,800 the dimensions being common with those of the last two preceding paragraphs, the cross-section was altered by variation in bottom slopes. The excavation was in sand trench and the flat roof and walls of the sewer were more heavily reinforced to meet the loading due to backfilling.

(13) From footage 31,800 to 32,838·52, the construction was similar in all respects to that from 26,248·96 to 26,825.

In the final length described, silt pits were constructed, the function of which is to enable depositable matter to be removed as far as practicable and thus prevent it from being deposited in the syphons. The

upstream ends of the silt pits agree with the position of the screening chamber, mentioned in the general description as being the upstream end of the construction.

In 1921 fissures were noticed in a length of the sewer extending for about 1,000 feet upstream from the point where it is crossed by Bunnerong Road, and after an attempt at grouting with cement had been made and in view of the imminent danger of collapse, it was decided in 1931 to place 8 feet 3 inches diameter steel cylinders within the barrel, which at this point is 10 feet by 11 feet 2 inches in cross section, and to fill the intervening annular space with good concrete. The combined effect of the reduction in size caused by the introduction of the cylinders, incidental loss of gradient and mechanical obstruction to flow at the invert, reduced the capacity of the sewer very materially, which with accruing demand from new areas brought about such a condition of affairs that it was recognised that considerable amplification to this outfall sewer had become necessary. This is dealt with in the succeeding chapter.

Low Level Sewerage

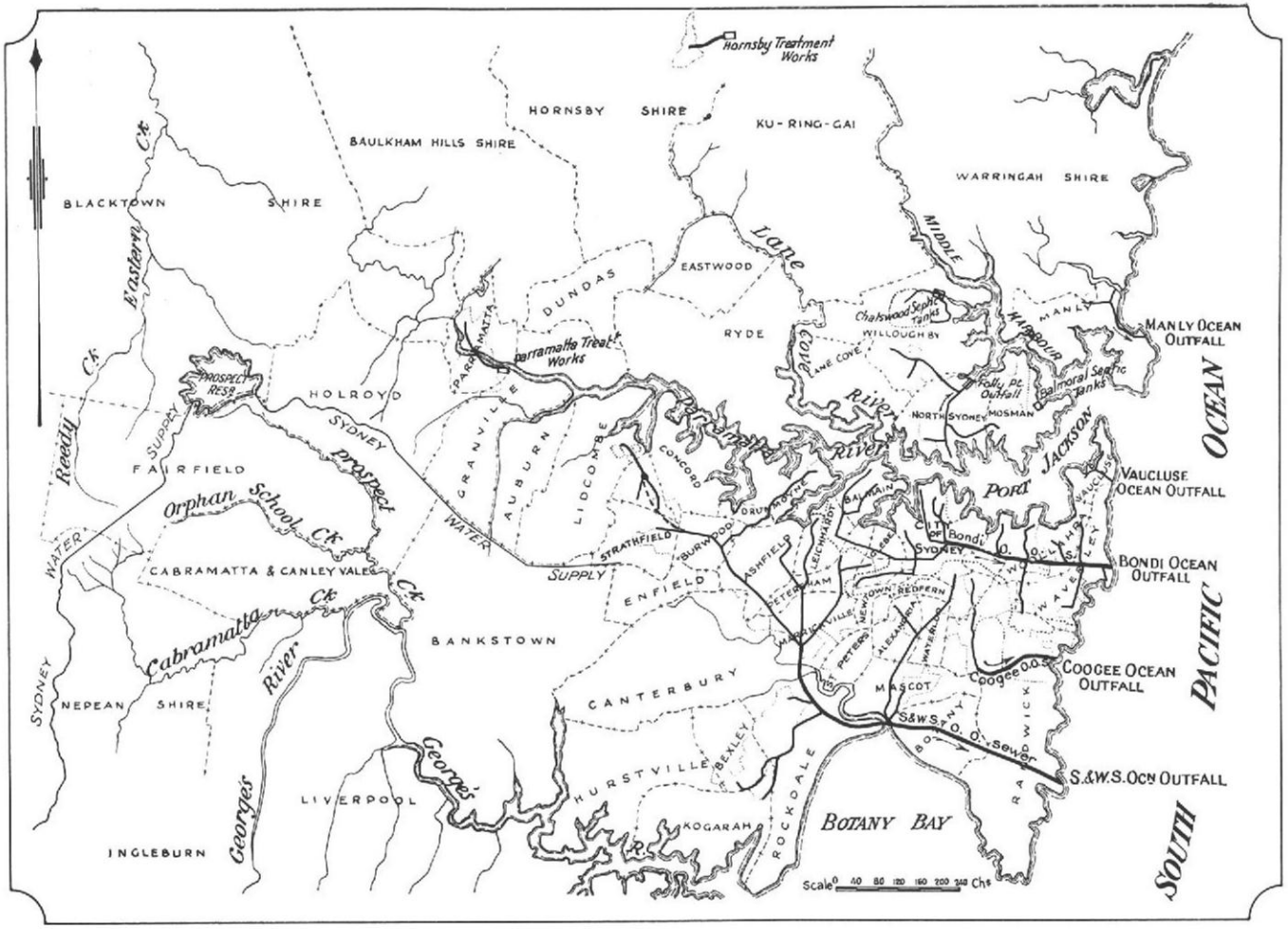
The following is a list of the electrical pumping stations which deliver directly to No. 1 Sewer:—

Year constructed	Station No.	Location	Low Level Area Served
1916 ..	38	Heath Rd., Botany	Cooks River Estuary and Ascot Racecourse.
1925 ..	60	Luland and Erith Sts., Botany	Botany Rd. and adjacent foreshores of Botany Bay.
1927 ..	73	Ivy St., Botany	Adjacent to Booralee Park.
1930 ..	74	Edgehill Av., Botany	Botany Rd., Sir Joseph Banks Rd., etc.
1929 ..	77	Bunnerong	Bunnerong Power House.

The number of houses drained to these pumping stations is 4,131. Approximate population served 17,500.

REFERENCES

Parliamentary Standing Committee, 1908, 1910 and 1916.
Proceedings of Civil Engineers, Vol. 148.—"Sewerage Systems of Sydney," by J. Davis.
Proceedings Institution of Civil Engineers, Vol. 212—Discussion by Messrs J. Davis, de Burgh, Dare, Burrows, Cook, etc. on Paper on "Ocean Outfall Sewers."



SEWERAGE SYSTEMS AT DATE OF COMPLETION (1916) OF SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER.

CHAPTER XXIV

SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER—SECOND PHASE—AND NORTH GEORGES RIVER SUBMAIN

Over a period of twelve years prior to 1936, considerable investigation had been made to ascertain the best means of coping with the increasing demand upon the Southern and Western Suburbs Ocean Outfall Sewer, it being realised that either the duplication of this sewer with outfall adjacent to the existing one near Long Bay, or the provision of a second main sewer having an outfall to the ocean elsewhere, would be necessary before long, not only to relieve the existing main sewer but also to enable the Illawarra Suburbs sloping to Botany Bay and the northern side of Georges River and the populous Bankstown district to be served. As a possible alternative to duplication of the main sewer to the ocean near Long Bay, a good deal of investigation was made of a scheme to construct a main sewer from a junctionary point with the existing main sewer on the western side of the former sewage farm at Rockdale, near what is now known as Barton Park, in a southerly direction a distance of 14 miles to Marley Head near Wattamolla, south of Port Hacking. This scheme involved the construction of two inverted syphons each 32 chains in length, one beneath Georges River and the other beneath Port Hacking.

At the same time as these alternative proposals for amplification of the Southern and Western Suburbs Ocean Outfall Sewer were being matured, the important question of the installation of treatment works at all the ocean outfalls to remove the nuisance caused by floating matter from the sewer outfalls being washed on to the bathing beaches, was engaging the serious attention of the Board. It was recognised that the Marley Head proposal, costly and risky from the engineering standpoint, left this major problem unsolved as it would only enable a relatively small portion (12 per cent) of sewage to be conveyed to an ocean outfall distant from the bathing beaches. The diversion of existing ocean outfalls to Marley Head being out of the question on account of the engineering difficulties and the tremendous cost, the whole of the issues involved came before the Board for consideration in January, 1936, when the following resolutions were adopted:—

(A) "The Board records its adherence to the principle of disposing of sewage by direct discharge into the ocean where the cost of so doing is not excessive, and directs that steps shall be at once taken with a view to equipping present and future outfalls with suitable and efficient treatment works to remove matter liable to create nuisance from the sewage before discharge of same into the sea."

(B) "That the amplification of sewerage facilities in the Southern and Western Suburbs be carried out by the construction of a Southern and Western Suburbs Ocean Outfall Sewer No. 2 from the old sewage farm, Rockdale, to the ocean at Long Bay."

During consideration by the Board the main objections raised to the Marley Head (Wattamolla) Outfall Scheme were:—

(1) Engineering difficulties and risks connected with the construction of the inverted syphons under Georges River and Port Hacking as disclosed by trial bores.

(2) Extra length and extremely flat grade of the sewer. The length would be 14 miles compared with 7 miles to Long Bay and the grade 1 in 8,000 (1 ft. in 1½ miles) compared with 1 in 3,893, the flattest grade to Long Bay. No record could be found of a sewer being laid anywhere at anything like such a flat grade as 1 in 8,000.

(3) Higher cost compared with duplication of main sewer to Long Bay estimated at over £2,000,000. The cost of installing the most up-to-date treatment works at all existing ocean outfalls, it was considered, would not amount to anything like this sum, and this expenditure would have still to be faced if the Wattamolla Scheme was carried out.

There was a considerable amount of criticism of the Board's decision to abandon the Marley Head or Wattamolla Outfall Scheme, based on the false premises that this scheme could be ultimately developed to supersede all existing ocean outfalls south of the Harbour discharging near the metropolitan bathing beaches, and the fear that it was not practicable to instal such treatment works at any of the existing or future ocean outfalls as would eliminate all risk of nuisance from sewage matter on the beaches. In view of the criticism referred to, the Board was urged by the Minister for Works and Local Government, (Hon. E. S. Spooner, M.L.A.), to obtain independent expert advice on its proposals. The Board accepted the Minister's suggestion and referred the proposal to Messrs A. J. Gibson, M.E., M.Inst.C.E., M.I.E. Aust., of the firm of Julius Poole and Gibson, Consulting Engineers, Sydney, and

H. H. Dare, M.E., M.Inst.C.E., M.I.E. Aust., formerly Commissioner for Water Conservation and Irrigation. The terms of the two resolutions adopted by the Board and quoted earlier herein were submitted to these two gentlemen for consideration in their investigations as being based on the presumptions:—

(1) That it is necessary to eliminate or avoid any nuisance on the metropolitan bathing beaches from either existing or future outfalls, particularly during the bathing season.

(2) That it is practicable to do this by suitable and inoffensive treatment, either near the outlets or along the length of any existing outfalls or any duplication of the outfall leading to Long Bay.

(3) That having regard to (2), it is unnecessary to consider any scheme involving the interception of any of the existing outfall sewers, and the diversion to a distant southerly point of the sewage carried by it or them.

(4) That for the same reason and on account of the reduced charges, both of first cost and maintenance, it is preferable to amplify the present Southern and Western Suburbs Outfall Sewer by the construction of another outfall leading to Long Bay rather than by that of an outfall leading to Marley Head, and having regard to the resolutions and presumptions quoted they were asked to investigate as follows:—

(i) As to whether presumptions (2), (3) and (4) and the conclusions reached in the light of them are such as they can endorse.

(ii) If not, in what respect is amendment considered necessary.

After a very complete investigation of the Board's proposals as well as of the whole question of sewage disposal by ocean outfalls and treatment works, Messrs. Gibson and Dare submitted a report in March, 1936, giving unqualified approval to the principles upon which the Board had arrived at its decision in respect of duplication of the Southern and Western Suburbs Outfall Sewer to Long Bay, and the installation of treatment works at all existing and future ocean outfalls. All reasonable doubts as to the soundness of the Board's proposals being cleared away, preparations were immediately put in hand for the construction of the No. 2 sewer to Long Bay and its main arm, the North Georges River Submain, which will enable the Illawarra Suburbs and Bankstown to be completely sewered. Operations are being pushed on with the utmost celerity, recognising that sewerage facilities to the populous suburbs referred to cannot be given until these two works have been completed.

Construction Details Southern and Western Suburbs Ocean Outfall Sewer No. 2

The general layout of this sewer is, firstly, to discharge to the ocean in close proximity to the outlet to No. 1 Sewer, by two outlet legs at similar level to that adopted for the outlets to No. 1 Sewer. Secondly, to carry the flow in one barrel where economical construction would permit same. Thirdly, to excavate in rock tunnel wherever the plane of the sewer allowed for such. Fourthly, to limit the depth of sand trench to the smallest permissible extent. Fifthly, to avoid the unstable ground experienced in the water-charged section of the No. 1 Sewer, and finally, to place the plane of the sewer so that the flow may be diverted from this sewer to No. 1 and vice versa, by means of cross-connections wherever practicable. The size of the sewer was estimated upon the total demand from the whole area to be sewered, after allowing that No. 1 Sewer became restored to its full capacity by amplifying the repaired section. The sewer is under construction by day labour. The applied gradient between the outlet shaft and Cook's River is 1 in 3,893·7, while upstream from that river, the mean gradient is about 1 in 2,550.

(1) The two outlet legs are to be constructed in rock tunnel six feet in diameter from an underwater cliff to the outlet shaft.

(2) For about 65 chains the sewer is 8 feet by 16 feet 2 inches, box section, plain concrete in rock tunnel.

(3) From chainage 65·00 to about 78·00 the construction being in soft ground, the sewer will be in twin barrels 6 feet 6 inches by 9 feet 5½ inches reinforced concrete. In view of the Board's decision to treat all sewage en route to the ocean, the essential treatment works will be placed in this length.

(4) From chainage 78·00 to about 181·00 the sewer is similar in all respects to that described in (1).

(5) From chainage 181·00 to 561·787 the sewer is of constant size, twin barrels 6 feet 6 inches by 9 feet 5½ inches cross-section in reinforced concrete, with the exception of the Cook's River Syphon. There are several lengths of deep sand trench up to 30 feet in depth, considerable lengths of very shallow excavation, but the greater part is in aqueduct. The barrels are laid on a reinforced concrete mattress, supported upon piles in certain ground. The Cook's River Syphon is laid in two barrels 6 feet 6 inches in diameter.

(6) The upstream end of this work is situated at the old screening chamber 6·17 chains downstream from the junction of the Illawarra submain (Eastern Division) with the No. 1 Outfall. Supplementary pits will be placed in the new sewer opposite the existing silt pits on No. 1 Sewer.

(7) At chainage 561·787 the flow from the most important branch of the new system, i.e. the North Georges River Submain, together with that from the Western Suburbs Carrier, is met and immediately divides into the Nos. 1 and 2 sewers relative to their respective carrying capacities.

(8) The North Georges River Submain is under construction and varies in size from 7 feet 8 inches by 12 feet to 7 feet 3 inches by 7 feet 7 inches box section. The excavation varies between long lengths of rock tunnel and short lengths of aqueduct. The semi-elliptical arched roof varies in camber from 1 foot 8 inches to 1 foot 3 inches in accordance with the width. The gradient varies from 1/3651 to 1/2722.

(9) Upstream from the North Georges River Submain the West Bankstown Submain will be constructed, commencing at 7 feet 3 inches by 7 feet 7 inches box section, in tunnel, trench and aqueduct, reducing to 3 feet 6 inches and finally 3 feet in diameter to its upstream end in South Bankstown.

REFERENCES

"Major Amplification of the Southern and Western Suburbs Ocean Outfall System," S. T. Farnsworth, B.Sc. (Eng.), M.Inst.C.E., Engineer-in-Chief, Metropolitan Water Sewerage and Drainage Board, 1936.

"Elimination of Nuisance from Ocean Outfall Discharges, and Treatment Works." S. T. Farnsworth, B.Sc. (Eng.), M.Inst.C.E., 1936.

CHAPTER XXV

NORTH SYDNEY—MOSMAN SEWERAGE

The original North Sydney Sewerage System, the main portion of which was constructed by the Government between 1891 and 1898 and transferred to the Board in 1899, provided for the sewerage of that part of Willoughby south of Mowbray Road and east of Lane Cove Road (now Pacific Highway), all North Sydney, and Mosman with the exception of the area bounded by Spit Road, Military Road, Bradley's Head Road and the Military Reserve, which, sloping towards Middle Harbour (Balmoral), was later provided with a separate system draining to septic tanks near Balmoral Beach.

The main outfall sewer discharged the sewage to treatment works situated at the head of Willoughby Bay, also known as Long Bay, Middle Harbour, where an area of 5 acres of Crown Land was appropriated in 1892, and about 8 acres reclaimed from tidal waters. Various small parcels of land were added subsequently by purchase or resumption, making the total area 19 acres 2 roods 27·9 perches. The sewage on reaching the treatment works had the larger solids removed by screens and the screened matter was burned. The sewage after lime dosing (1 ton per million gallons) was run into open settling tanks. The supernatant water was decanted on to sand filter beds having subsoil drains with coir mat joints, the effluent being discharged into the tidal waters of the bay. The sludge from the settling tanks was run into two steel lined cylindrical chambers where more lime was added. Compressed air was then applied and the sludge forced through filter presses. The pressed sludge in the form of cakes was then burned in a furnace and buried at the site of the works.

In 1900, soon after the works were transferred to the Board, it was decided to convert one of the precipitating tanks into a septic tank of the Scott-Moncrieff type with a view to the abolition of lime precipitation and fuel burning of sludge which were too costly for the largely increased volume of sewage which would have to be dealt with in a few years time. In 1901 the lime precipitation was abandoned and open septic

tanks adopted, the effluent flowing on to sand filter beds which were planted with crops. In 1903, in view of complaints as to nuisance, the open tanks were covered in with reinforced concrete. By 1912, it was reported that the treatment works were taxed to full capacity, and enlargement of the septic tanks was necessary. Detritus tanks and trickling filters were constructed to relieve the sand filter beds which were becoming sewage sick. At this time also in view of complaints from the surrounding localities which were becoming extensively built upon, the Board's staff was carrying out investigations for an intercepting sewer to discharge the sewage into the ocean at Bluefish Point, North Head, but it was recognized that such a work would take several years to complete from the date it was actually commenced. Meanwhile additional liquefying tanks were constructed and further action was proposed to increase the capacity of the works.

In 1919, the representatives of the Cooper Estate, which owned a considerable area of land overlooking the treatment works, instituted Equity Court proceedings against the Board for negligence and nuisance in the conduct of the works. The hearing of the suit extended over several weeks, and in the end while the count of negligence was not upheld an injunction was granted, restraining the Board from operating the works in any way that caused nuisance to the neighbourhood. As one of the difficulties the Board had to contend with was the large and rapidly increasing flow of sewage to be dealt with, it was compelled by reason of the Equity injunction to suspend all further extensions of the sewers pending additions and alterations to the works. Steps were promptly taken to install the activated sludge process of treatment, and at the same time to chlorinate the effluent from the septic tanks. Owing to war conditions then existing it was not possible to obtain supplies of chlorine, and the expedient had to be adopted of obtaining the chlorine from the sea water by a process of electrolysis. The chief difficulty in operating the activated sludge process was the disposal of the sludge. At first it was towed to sea in punts but later it was discharged as it accumulated in the activated sludge tanks into the septic tanks. This proved so effective that punting the sludge to sea was definitely abandoned.

The necessity of suspending sewer extensions and new connections to the sewers in the area served by these treatment works caused a general outcry from the councils concerned; builders and landowners were anxious to erect residences but were not prepared to do so without sewerage facilities being available. The Board was, however, compelled in view of the terms of the injunction of the Equity Court to refrain from doing anything that might have been held to be contempt of the

injunction until it was clearly demonstrated that the alterations and modifications of the system which were being carried out enabled it to remove the embargo with safety.

The system of combined septic and activated sludge tanks continued in operation until 1927, when the Northern Suburbs Ocean Outfall Sewer was completed up to a point which enabled the sewage to be diverted into same and so conveyed to the ocean at Bluefish Point north of North Head. The works so far as realisable plant was concerned were dismantled. The land was sold in 1929 to the North Sydney Council for park purposes and the area is now known as Primrose Park.

As illustrative of the growth in the area draining to these treatment works the following figures are quoted:—

1905	No. of houses drained			5,642	Approx.	Population	served	28,210
1915	,,	,,	,,	10,167	,,	,,	,,	50,520
1927	,,	,,	,,	14,043	,,	,,	,,	70,000

Mosman Septic Tanks.—These septic tanks, which treated the sewage from the area facing Middle Harbour bounded by the Spit, Military and Bradley's Head Roads, Cross Street and the Military Reserve, were constructed by the Public Works Department and transferred to the Board in 1904. The tanks were built on the Military Reserve on the eastern side of Hunter Bay. The installation consisted of four septic tanks and eight filter beds, the effluent running into Middle Harbour. The filters were actuated by the Cameron-Martin automatic alternating gear of the latest type. In September, 1927, these treatment works ceased to function, the whole of the sewage hitherto discharging into them being intercepted by a branch of the Northern Suburbs Ocean Outfall Sewer, which had been completed up to the stage which enabled this to be effected. The works were later dismantled and all material which could be used again recovered.

There were 1,295 houses draining to this outfall when it ceased to operate, the population served being then about 6,000.

North Sydney Main Sewer.—This sewer was constructed by the Government and transferred to the Board in 1898. Commencing at the treatment works, Willoughby Bay, it was laid in a south-westerly direction through private property, across Cammeray Park to Ernest and Alfred Streets, thence generally in a south-easterly direction terminating in Campbell Street. Dimensions of sewer—4 feet by 3 feet diminishing gradually to 3 feet 3 inches by 2 feet 2 inches. It was connected in 1927 to the Northern Suburbs Ocean Outfall Sewer which superseded the treatment works.

Main Branch Sewers.—The following main branch sewers draining into the outfall sewer were constructed by the Government and transferred to the Board in the years indicated:—

1898—Lavender Bay and Blues Point Branch:

This branch joins the outfall sewer in Alfred Street at McDougall Street, and extends westerly to Holt Street and southerly to junction of East Crescent Road and East Street. With its submains this branch serves the reticulation of the main portion of North Sydney. The Wollstonecraft branch joins the Lavender Bay branch at Holt Street and extends westerly and northerly along Woolcott and King Streets to Gore Creek.

1900-1902—Neutral Bay and Mosman Branch:

This branch joins the outfall sewer at Alfred and McLaren Streets, North Sydney, extending easterly along the foreshores of Neutral Bay at the head of Shell Cove, thence across Reid Park, Mosman, on a steel bridge to Avenue Road, thence to Little Sirius Creek. This branch with its submains serves the reticulation of Neutral Bay and Mosman, with the exception of the Balmoral Beach slopes of the latter suburb.

1901—South Willoughby Branch:

This branch joins the main outfall sewer near the treatment works and extends thence westerly and north-westerly crossing Cammeray Road, West Street, Wharf Street and Garland Street to Willoughby Road and thence to Flat Rock Creek. It serves the reticulation of Willoughby south of Mowbray Road.

1904—Middle Harbour Slopes Main Sewer:

This sewer extends from the treatment works easterly along the foreshores of Middle Harbour. It serves the reticulation of the inner Middle Harbour slopes of Neutral Bay and Mosman, now intercepted to the Northern Suburbs Ocean Outfall Sewer.

1904—Balmoral Slopes Main Sewer:

This sewer extended from the Balmoral septic tanks in a general westerly direction to creek near Almora Street (crossing Raglan Street) thence northerly crossing Mandalong Road to creek. It serves the reticulation of the Balmoral slopes of Mosman, and is now intercepted by the Northern Suburbs Ocean Outfall Sewer in parts, the residual length being abandoned.

North Sydney Low Level Sewerage.—The following is a list of electrical pumping stations (automatically controlled) operating in connection with the sewerage of the low levels of North Sydney and Mosman. The function of these pumping stations is to pump sewage which flows into

the receiving chambers from low level reticulation systems into the most convenient submains of the systems gravitating to the outfall.

Year constructed	Station No.	Location	Low Level Area Served
1907 ..	24	George St., Nth. Sydney	Lavender Bay, Watt Park and McMahon's Point
1913 ..	32	Jeffrey St., Nth. Sydney	Along foreshores Kirribilli
1913 ..	33	MacDougall St., Nth. Sydney	Along foreshores, Careening Cove to Kirribilli
1930 ..	34	Clarke Rd., Neutral Bay	Around Warringbah Park
1926 ..	54	Clifton Gardens, Mosman	Clifton Gardens
1929 ..	57	Cremorne Pt., Nth. Sydney	Foreshores at Cremorne Point
1927 ..	69	Lawry Pde., Balmoral	Foreshores at Balmoral Beach
1927 ..	70	Ruve St., Balmoral	
1929 ..	79	Blues Pt., Nth. Sydney	Foreshores at Blues Pt.

LOW LEVEL AREAS

1911	No. of houses drained		40	Population served		..	200
1921	"	"	"	119	"	"	.. 595
1938	"	"	"	829	"	"	.. 3,500

The above figures relate to the resident population served.

Most of these low level areas, however, embrace reserves along the water front in connection with which lavatories exist which are visited at week-ends and on public holidays by large numbers of the public, and without the sewerage service provided by these low level installations, insanitary conditions of an intolerable nature would be set up.

REFERENCES

Report on Disposal of North Shore Sewage. By E. C. B. Smyth, 1888.
Parliamentary Standing Committee, 1888.

CHAPTER XXVI

WILLOUGHBY-CHATSWOOD SYSTEM

The outfall works (septic tanks) and main sewer were constructed by the Public Works Department and transferred to the Board in 1899. The sewage from the greater portion of Willoughby, north of Mowbray Road and east of Gordon Road (now Pacific Highway), drained to this system. An area of about 25 acres was resumed, $4\frac{1}{4}$ acres in 1900 and $20\frac{1}{2}$ acres in 1902, in connection with the treatment works and main sewers. The main sewer emptied into a carrier which discharged into septic tanks, the effluent from which was further treated on coke filter beds before being finally discharged into Scotts Creek, Middle Harbour. The tanks received the discharge from two main sewers as under:—

Sugarloaf Creek Main Sewer.—Constructed by the Board in 1916. It extended south-easterly from the tanks to Sugarloaf Creek, and serves the Middle Harbour slopes of Willoughby north of Mowbray and Edinburgh Roads.

Middle Harbour Slopes Main Sewer.—Constructed by the Board in 1916. It extended south-easterly from the tanks to Sugarloaf Creek, and serves the Middle Harbour slopes of Willoughby between Boundary Street and Edinburgh Road.

The interception of these two sewers by the West Middle Harbour branch of the Northern Suburbs Ocean Outfall Sewer resulted when the latter was completed in 1927. The Chatswood septic tanks ceased to operate thereafter.

The large area resumed when the works were constructed is still held by the Board, awaiting a favourable opportunity for disposal. The locality is not a progressive one, being adjacent to tanneries.

1906	No. of houses connected			831	Approx. population served			4,000
1916	,,	,,	,,	1,731	,,	,,	,,	8,000
1926	,,	,,	,,	3,553	,,	,,	,,	17,000
1938	,,	,,	,,	10,550	,,	,,	,,	47,000

CHAPTER XXVII

PARRAMATTA SEWERAGE

A scheme for the sewerage of Parramatta was constructed by the Public Works Department under and in accordance with the Parramatta Sewerage and Drainage Act of 1905, and the works were transferred to the Parramatta Municipal Council on completion, by proclamation dated 27th April, 1910. The works were constructed for the Council by the Government under terms and conditions as set out in the Act referred to, whereby the Council was to repay the Government the cost by annual instalments of principal and interest. The cost of the works as charged to the Council was £66,010, and the Council had paid off the principal, at the time the works were vested in the Board, a sum approximating £500. Act No. 13 of 1916 (Metropolitan Water and Sewerage Amendment Act, 1916) transferred from the Council to the Board all the lands, works and property of any kind, which at the date of the Act (17th April, 1916) were in the possession of the Council in connection with the sewerage of Parramatta, and the Board became charged in its Capital Account with the cost of the works less the amount repaid by the Council. The Council continued to collect the rates as agent for the Board from date of transfer until 31st December, 1916.

Pumping Station and Treatment Works.—The whole of the sewage flowed to a pumping station in George Street, Parramatta, whence it was pumped to septic tanks situated farther down the Parramatta River at its junction with Clay Cliff Creek. The filter beds in connection with the treatment works were of the contact type, and the flow thereto was controlled by automatic hydraulic gears. The two "Sands" centrifugal pumps were driven by two Hornsby gas engines. These during the control by the Council were supplied with gas from the septic tanks. When the Board took over, the station was converted to automatically controlled electric drive, as being more economical.

With the completion of the Northern Suburbs Ocean Outfall Sewer to Dundas, and the putting into commission in September, 1930, of the large sewerage pumping station constructed by the Board at Camellia, to collect the sewage from Parramatta, Lidcombe, Auburn, Granville and Holyroyd reticulation, and pump it into the ocean outfall sewer, the Parramatta treatment works and pumping station ceased to operate. The

old plant was dismantled, and part of the area acquired for the treatment works, a little over 3 acres, is occupied as a depot for maintenance purposes. Part of the plant was sold and the balance transferred to other works.

At the time these works were transferred to the Board there were 2,147 houses connected to the system, the population served being about 10,000. In 1930, when the treatment works ceased to operate, the sewage from 3,218 houses was being dealt with and the population served about 16,000.

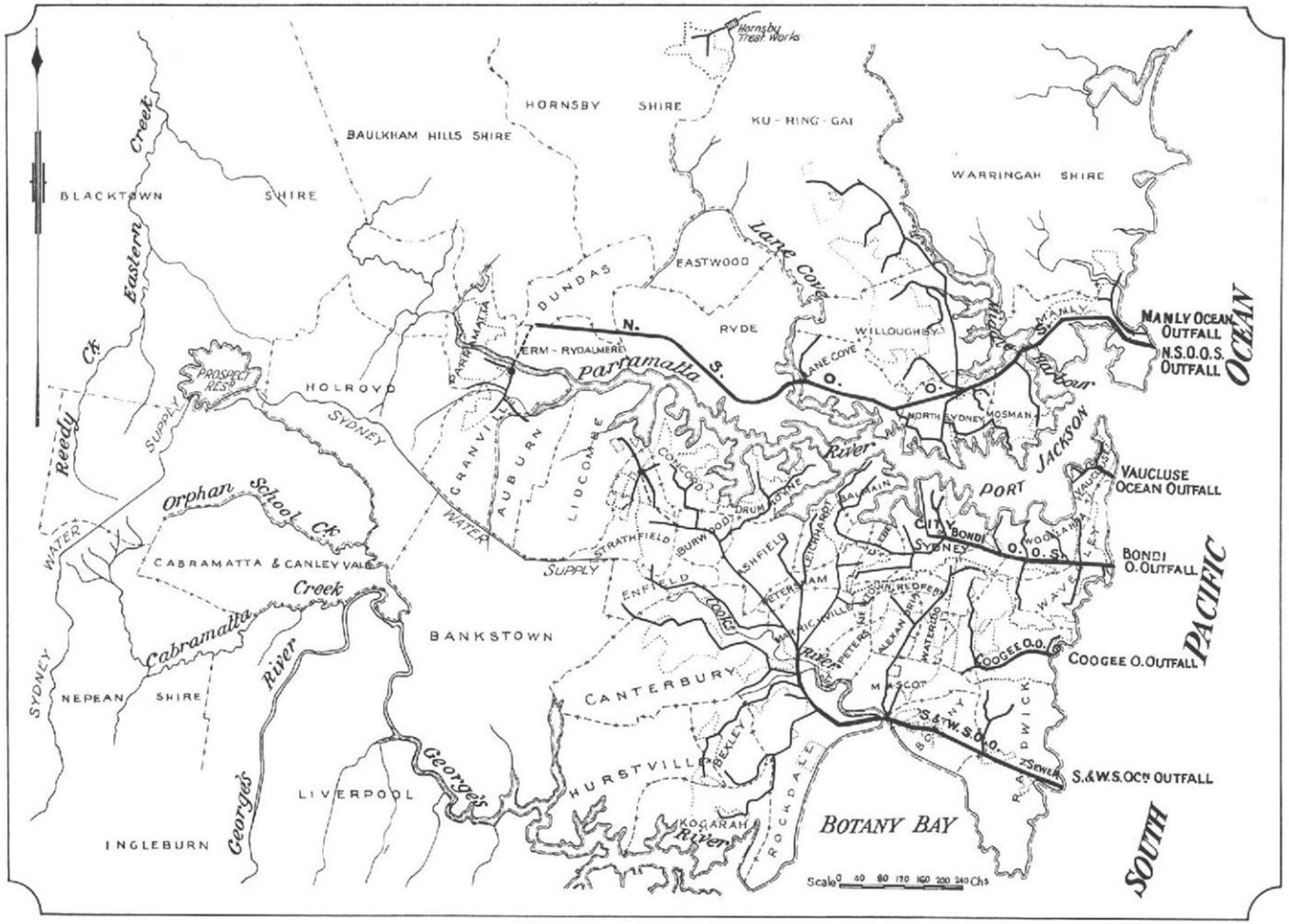
REFERENCES

Parliamentary Standing Committee, 1892, 1894, 1897.

CHAPTER XXVIII

NORTHERN SUBURBS OCEAN OUTFALL SEWER, ABSORBING NORTH SYDNEY-MOSMAN, WILLOUGHBY-CHATSWOOD AND PARRAMATTA SYSTEMS AND SERVING NORTHERN AND FAR WESTERN SUBURBS

It has already been mentioned, in the descriptive matter relating to the North Sydney Treatment Works in Chapter XXV, that in 1912 it was recognized that these works were rapidly approaching the limit of their capacity to accommodate and deal with the largely increased volume of sewage drainage thereto. A much larger area was being served than was originally intended, and the area of suitable land available was too limited to allow of adequate expansion of the works. In view of this and the extent of complaints from surrounding localities which were being extensively built upon, the Board's staff had commenced investigations regarding an intercepting sewer to discharge into the ocean at Blue Fish Point near North Head. The matter was a little later taken up by the then constructing authority (the Minister for Public Works) on a comprehensive basis, having in view not only the superseding of the treatment works at Willoughby Bay, Chatswood, Balmoral Beach and Parramatta, but of providing also an ocean outfall for the sewerage of the rapidly developing suburbs situated along the Milson's Point-Hornsby Railway, and the far Western suburbs which were not provided for in the original Western Suburbs Sewerage Scheme. The scheme as drawn up in 1914 provided for a large main sewer with several branches, having a discharge into the ocean at Blue Fish Point and terminating near Wentworthville station in the Municipality of Holroyd, after crossing *en route* beneath Middle Harbour and Lane Cove River and traversing Manly, Mosman, North Sydney, Lane Cove, Hunter's Hill, Ryde, Ermington and Rydalmere, Dundas, Parramatta, Baulkham Hills and Blacktown. The proposal was submitted in September, 1915, to the Parliamentary Standing Committee on Public Works, and recommended by that Committee to be carried out in its report dated 14th September, 1916. Construction work was carried on by the Public Works Department from 1916 until 1st September, 1928, on which date the work was transferred to the Board for completion under the provisions of the Metropolitan Water Sewerage and Drainage Act of 1924. At the time of transfer, the Main Outfall Sewer had been completed up to and inclusive of the 4th section, enabling the sewage to



SEWERAGE SYSTEMS AT DATE OF COMPLETION (1930) OF NORTHERN SUBURBS
OCEAN OUTFALL SEWER.

be intercepted which had hitherto discharged into the treatment works at North Sydney (Willoughby Bay) and Mosman (Balmoral). The 5th section, which terminated at the Lane Cove River, was almost completed, and the 6th and 7th sections were in progress. Construction operations in respect of these three sections were completed by the Board early in 1930.

The size of the concrete sewer at the ocean outfall at the cliffs at Blue Fish Point near North Head is 8 feet 9 inches by 13 feet 9 inches, diminishing to 8 feet 5 inches by 12 feet 4 inches, opposite the Spit at Clontarf. The total length to Dundas, at which point construction for the time being ceased, is 17 miles 61 chains, and the size at the point of termination is 7 feet 7½ inches by 8 feet 6 inches. Of the total length, 16 miles 44 chains were constructed in tunnel through ridges of a height of from 200 to 300 feet, the tunnel being lined with concrete of an average thickness of 9 inches. Five aqueducts were constructed to cross gullies. Th route necessitated the crossing of Middle Harbour and the Lane Cov- River by means of inverted syphons. The syphon under Middle H' -bour is 1,174 feet in length and consists of duplicate pipes 6 feet in ameter, laid on the bed of Middle Harbour from near the Spit to tarf, the depth of water being 72 feet near the centre. Each pipe 100 eet in length, weighing 150 tons, constructed of reinforced concrete, was fabricated on land and later placed in position by a floating crane, made available by the naval authorities. The arrangement of ; es at the joints, and the method of jointing have proved effective. he Lane Cove syphon is 872 feet in length. A tunnel 13 feet by 7 fee as driven through sandstone from shaft to shaft. Duplicate 4 feet 6 i ies diameter reinforced concrete pipes were laid in the tunnel with a towards the downstream end, and the intervening spaces betwee ie tunnel lining and the pipes filled with concrete. Each inverted syphon has duplicate barrels, only one barrel being required for the dry weather demand. The efficiency of both is maintained by periodical scouring, the necessary head being provided by ponding the flow upstream for some hours.

All the reticulation from Parramatta, Granville, Holroyd, Auburn and Lidcombe gravitates to Camellia Pumping Station, and from there is lifted into the outfall sewer at a point near Dundas railway station.

The Board is at present constructing the 8th section of the outfall sewer from Dundas to Northmead, which will enable areas in Blacktown and Baulkham Hills Shires, North Parramatta, etc., to be sewered.

Branch Sewers:

The following main branch sewers have been extended from the Northern Suburbs Ocean Outfall Sewer:—

West Middle Harbour Branch.—Constructed by the Public Works Department and transferred to the Board on 11th November, 1927. It extends from the main sewer at Cammeray Park to Rocky Creek, Gordon. It varies in size from 4 feet circular to 3 feet 3 inches by 2 feet 2 inches, finally terminating in a 4-ft. circular pipe. Four aqueducts were constructed along the line of this sewer, viz., at Long Bay and Sugarloaf Bay, Middle Harbour, Moore's Creek, Roseville, and Gordon Creek, Lindfield. The following submain sewers drain into this branch sewer:—

(a) *Sugarloaf Creek and Scotts Creek Submains.* These two submains originally drained to the Chatswood septic tanks but were diverted to the West Middle Harbour Branch of the Northern Suburbs Ocean Outfall in 1927.
(b) *Moores Creek or Roseville Submain.* Constructed in 1927.
(c) *Gordon Creek or Lindfield Submain.* Constructed in 1928.
(d) *Rocky Creek or Lindfield-Gordon Submain.* Constructed in 1929.
(e) *Stoney Creek or Gordon-Pymble Submain.* Constructed in 1929.

The construction of these four submains enabled sewerage facilities to be extended to the Middle Harbour slopes of the populous residential districts of the Ku-ring-gai municipality.

(f) *Sailors Bay Submain.* Constructed in 1937. This serves that portion of Northbridge sloping towards the southern side of Sailors Bay, Middle Harbour.

East Lane Cove Branch.—The first section of this branch sewer was constructed by the Public Works Department and transferred to the Board in September, 1928. It extends from the Lane Cove River syphon northerly to Stringy Bark Creek, Lane Cove. Extensions were carried out by the Board between 1929 and 1937, and have reached Terrys Creek, Eastwood, a distance of about 6 miles. The sewer varies in diameter from 5 feet to 4 feet; sewer aqueducts have been constructed at Swaines Creek, Blue Gum Creek, Little Blue Gum Creek, de Burgh's Creek, Rudder's Creek, Quarry Creek and an unnamed creek near Busaco Road, Eastwood. The following submain sewers drain to this branch sewer:—

(a) *Stringy Bark Creek Submain.* Constructed in 1935.
(b) *Swaines Creek north and south Submains.* Constructed in 1937.
(c) *Blue Gum Creek north and south Submains.* Constructed in 1937.
(d) *Little Blue Gum Creek north and south Submains.* Constructed in 1937.
(e) *de Burgh's Creek Submain.* Constructed in 1937.
(f) *Terry's Creek Submain.* Constructed in 1937.

Submains (a) to (e) serve areas which embrace the western slopes of Willoughby and those portions of the Ku-ring-gai municipality sloping in a westerly direction to the Lane Cove River.

Submain (f) enables sewerage facilities to be given to the whole of the business centre of Eastwood, the southern portion of Epping and small portions of Dundas and Ryde not draining directly into the 6th and 7th sections of the main sewer.

West Lane Cove Branch.—This branch sewer junctions with the main sewer near the western extremity of the Lane Cove River syphon and extends thence to the intersection of the Strand and Pittwater Road, Ryde. The sewer is 4 feet 6 inches in diameter. From its present terminal point the Buffalo Creek submain extends along that creek to Lane Cove Road, Ryde. This submain serves the business centre of Ryde. The West Lane Cove Branch will be extended to serve those parts of Eastwood and Ryde sloping westerly to the Lane Cove River. Submains extending from the main sewer serve the districts of Greenwich, Longueville, Woolwich, Huntley's Point and Gladesville.

REFERENCE

Parliamentary Standing Committee, 1916.

CHAPTER XXIX

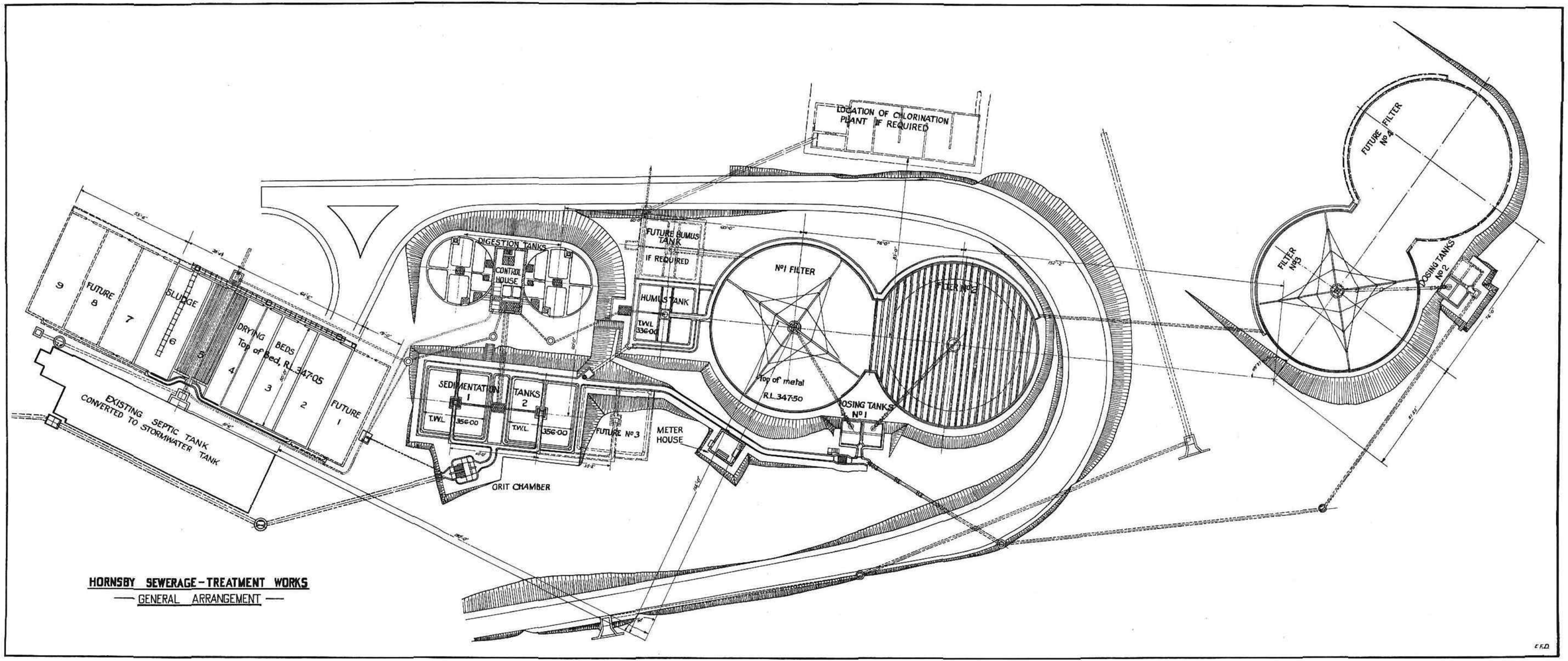
HORNSBY SEWERAGE SYSTEM

The Hornsby sewerage works were commenced by the Public Works Department in 1911, but after the work had proceeded for some months, the Board, at the request of the Minister for Public Works, took over construction operations. The scheme, including treatment works, main sewer, and reticulation, was completed and put into commission in 1915. It was designed to serve the closely occupied Hornsby township area and the settled area on the northern side of the railway easterly to just beyond Waitara station.

Treatment Works.—These consist of septic tanks discharging on to percolating filter beds, constructed on the high ground above the intersection of Hornsby and Spring Gully Creeks. The effluent flows down the latter creek along a rough and steep valley, which is uninhabited, to the waters of Cowan Creek, a saltwater branch of the Hawkesbury River. An area of 32 acres 1 rood 33½ perches of Crown lands was appropriated on 5th November, 1913, to accommodate the works.

Main Sewer.—This extends from the treatment works in aqueduct across the gully in a south-westerly direction to Sherbrook Road, where it bifurcates, one branch extending towards Hornsby station and the other towards Waitara station. The scheme originally served 162 houses, and population of about 800. At 30th June, 1938, the number of houses drained was 1,312 and the population served about 5,600. The length of sewers draining to the treatment works had during the same period increased from a little over 3 miles to 31·1 miles.

Expansion of the Scheme.—In order to meet the increased flow of sewage from the area embraced in the original scheme, and to permit of the sewering of those portions of Wahroonga and Mt. Errington whose natural drainage direction is towards the treatment works, the enlargement and improvement of these works have now been carried out. A submain sewer to serve the new areas has been constructed.


LOCATION OF CHLORINATION PLANT IF REQUIRED
FUTURE FILTER No 4
FILTER No 3
DOSING TANKS No 2
DIGESTION TANKS
CONTROL HOUSE
FUTURE HUMUS TANK IF REQUIRED
HUMUS TANK
TWL 336-00
No 1 FILTER
FILTER No 2
Top of metal R.L. 347-50
DOSING TANKS No 1
SEDIMENTATION TANKS
1
2
TWL 356-00
TWL 356-00
FUTURE No 3
METER HOUSE
GRIT CHAMBER
EXISTING SEPTIC TANK CONVERTED TO STORMWATER TANK
SLUDGE DRYING BEDS
Top of Bed, R.L. 347-05
9
8
7
6
5
4
3
2
1
FUTURE
FUTURE
HORNSBY SEWERAGE - TREATMENT WORKS
GENERAL ARRANGEMENT

CHAPTER XXX

MANLY SEWERAGE SYSTEM

The original works in connection with Manly sewerage were carried out during 1899 by the Public Works Department, and were vested in and managed by the local council until, by the Manly Water Supply and Sewerage Transfer Act No. 5 of 1902, they were vested in the Board as from 1st January, 1902.

Outfall Sewer.—This consists of an oval concrete main in size from 3 feet 9 inches by 2 feet 6 inches to 3 feet 6 inches by 2 feet 4 inches. It discharges into the Pacific Ocean at the base of an abrupt cliff 160 feet high, at the northern end of the Quarantine Ground near Shelly Beach Reserve, the spot being well protected from wave action. The invert of the outfall is 3 feet below high water mark owing to the low level of the town of Manly. A drop in the invert at a shaft near the mouth of the sewer, together with an expanding chamber near the outlet with a wave funnel, have been provided to minimise the effect of any wave inrush. This main sewer has not been intercepted by the Northern Suburbs Ocean Outfall Sewer, but certain reticulation lines have been intercepted as indicated later. The original construction of the outfall sewer extended from the outlet at Shelly Beach Reserve to the intersection of the Corso and South Steyne. The following extensions of the main sewer have been made by the Board in the years indicated:—

1911 Extended in concrete to the intersection of Pine Street and Pittwater Road, a distance of 64 chains.

1913 Further extended in concrete to a point at the intersection of Balgowlah Road and Suwarrow Street, a distance of 20½ chains.

1923 Further extended in monier pipes to a point in Balgowlah Road, east of Hill Street, a distance of 26 chains.

1931-1937 The extension known as the Burnt Bridge Creek Submain was constructed in four stages a total distance of 114½ chains.

Branch Sewers.—The original works taken over included two branch sewers. One extended along Ashburner Street and the Esplanade to Stuart Street and with an extension in tunnel constructed by the Board in 1908 provided for the reticulation of the whole of the area between the Corso and St. Patrick's College and the Cardinal's Palace. A con-

siderable portion of this area was intercepted by the Northern Suburbs Ocean Outfall Sewer at four points during its construction in 1927. The second branch extended from the main sewer westerly along Sydney Road thence to the Esplanade and along the Esplanade and the Park to Margaret Street. A tunnel extension of this branch was constructed by the Board in 1908 to permit of the reticulation of the Fairlight subdivision. This branch serves the reticulation of the township area north and east of the Corso. A third branch known as the Queenscliff Submain was constructed by the Board in 1912 and extended from the main sewer at Pine Street to a point in Collingwood Street near Bonner Avenue, a distance of 28 chains. In 1929 to enable the settled areas of Warringah Shire, i.e., Harbord and Queenscliff, to be sewered this submain was extended by syphon (18-inch cast iron pipes in duplicate) 13 chains in length across the Manly Lagoon and for a further distance of 63½ chains to Wyndora Avenue, Harbord.

Low Level Sewerage.—There are three low level areas for which pumping stations have been provided as follows:—

Year constructed	Station No.	Location
1915	35	Collingwood Street, Manly, near Lagoon
	36	Hutton Street and Old Pittwater Road
	37	Pittwater Road opposite tram sheds

REFERENCE

Parliamentary Standing Committee, 1888.

CHAPTER XXXI

RANDWICK SEWERAGE SYSTEM

The Coogee Outfall Sewer and its main branches were constructed by the Government and transferred to the Board, the main outfall in June, 1900, and the branch sewers in October, 1905. Prior to the transfer at the end of 1889 of the sewerage of Sydney and suburbs to the Board of Water Supply and Sewerage, the construction of the outfall sewer had been commenced by the Government on behalf of the Randwick Municipal Council, which had raised an amount of £9,000 by debentures from the Savings Bank of New South Wales. This sum only sufficed to cover cost of construction of the outfall sewer a short distance, viz., to the corner of Dolphin and Beach Streets. It was then arranged between the Government and the Council that the work should be continued by the former as part of the general scheme of sewerage of Sydney and suburbs, and be transferred on completion to the newly formed Board of Water Supply and Sewerage, and form part of its capital debt. As part of this arrangement, the Board provided the funds for liquidation of the Council's debentures in 1892. The main sewer discharges into the ocean north of Coogee Bay. From thence it extends to Dolphin Street and along that street to Melody Street, then south-west to Rainbow Street, crossing Avoca Street at Howard Street and terminating at Eastern Avenue, Kensington. A branch sewer extends from the outfall sewer northerly along Beach Street to Clovelly Road. The Board in later years constructed branch sewers to serve Daceyville and Kensington, and extended the main sewer in a northerly direction from Eastern Avenue to Park Road, City, and from the same point constructed a branch along Doncaster Avenue across Randwick Racecourse and along Alison Road to Darley Road.

The main sewer at the outfall is 6-ft. by 4-ft. It diminishes in size by stages to 3-ft. 3-ins. by 2-ft. 2-ins.

Coogee Diversion Sewer—The construction of the Coogee Diversion Sewer by which the discharge of sewage into the ocean at Coogee was discontinued and diverted to the S. & W.S.O.O.S. outlet near Miranda Point, Malabar, marked the culmination of many years of strenuous endeavour. Commencing in 1920, there was much agitation on the part of the local Council, Surf Clubs and Progress Associations, regarding

the condition of Coogee Beach when strong easterly or north-easterly winds were blowing. As these winds are the prevailing ones during summer when the beach is most used for bathing, it was felt that the Board should take some action to obviate the nuisance. After due consideration, the diversion of the outfall was decided upon in 1928, but realising that this work might take a few years to complete, the Board meanwhile installed at the existing outfall, as a palliative, a plant for mechanically disintegrating the floating sewage solids. The plant was put into operation in 1928. In the same year a contract was let for the construction of the first section of the diversion sewer. This section consisted of approximately one mile of concrete sewer, 6-ft. in diameter, through the Long Bay rifle range. It was completed in 1931 at a cost of £58,000. Work on the remaining four sections could not be commenced owing to financial stringency until 1933, when the State Government arranged for a loan of £2,500,000 to the Board for the purpose of carrying out a programme of relief works. The completion of the Coogee Diversion Sewer formed part of this programme. The work was commenced in October, 1933, and was continued to completion in July, 1936, this being marked by an official opening ceremony on the 25th July, 1936, by the Hon. E. S. Spooner, M.L.A., Minister for Public Works and Local Government, and the Hon. J. M. Dunningham, M.L.A., Minister for Labour and Industry. In addition to the Ministers mentioned, the President and Members of the Board entertained the Federal and State Members of the Constituencies concerned, the Mayors and officials of the Eastern Suburban Councils and representatives of local Surf Clubs and other kindred associations.

The total length of the diversion sewer including Clovelly Branch, is 3 miles 66.2 chains, of which 2 miles 49.5 chains is in tunnel. The total cost was £278,000. The sewer is constructed with concrete pipes, varying from 6-ft. to 5-ft. 6-ins. in diameter.

The construction of this diversion sewer also enables the ocean slopes of Maroubra to be reticulated.

At the time of diversion of the outfall to Long Bay in July, 1936, there were 11,364 houses draining to it, the population served being approximately 50,000.

Pumping Station No. 40 constructed in 1928 and located at Gardeners Road opposite Cottenham Avenue, Mascot, receives the sewerage from a low level area adjacent thereto and pumps it into the Daceyville branch of the Coogee main sewer.

CHAPTER XXXII

VAUCLUSE AND DIAMOND BAY (OCEAN OUTFALL) SEWERAGE SYSTEMS

The construction of a sewerage scheme for the Municipality of Vaucluse was authorised by Act No. 15 of 1911. The ocean outfall and main sewer were constructed by the Public Works Department and transferred to the Board in August, 1918. The Vaucluse Outfall is into the ocean at Christison Park, about ¼ mile south of Macquarie Lighthouse.

The Main Sewer as transferred to the Board in 1918 extended from the outfall along the southern foreshore of Parsley Bay to Wentworth Road, at its intersection with Olola Avenue, near Vaucluse Park. It is constructed mainly in brick and concrete and varies in size from 3-ft. 3-ins. by 2-ft. 2-ins. to 2-ft. 1-in. by 1-ft. 6½-ins. The submerged circular outlet is 3-ft. in diameter.

Main Sewer Extensions—In 1921, the Board extended the main line a distance of 5 chains through Vaucluse Park, in monier pipes. In this section, an aqueduct was constructed 2½ chains in length. Again in 1925, the Board further extended the main sewer to the Carrara Hospital grounds a distance of 25 chains.

Watson's Bay Branch—This branch which was constructed by the Public Works Department and transferred to the Board in August, 1918, extends from the main sewer in Parsley Bay Reserve along the foreshore of Cliff Street, Watson's Bay, a distance of 72 chains.

Low Level Pumping Stations—There are three low level areas, two draining to pumping stations Nos. 50 and 51 on the eastern foreshores of Watson's Bay, and No. 49 situated in Nielsen Park, which deals with the sewage from the park lavatories.

The total area drained to the Vaucluse Outfall is 533 acres, and the number of houses served at 30th June, 1938, was 1,786; population approximately 7,600.

Diamond Bay No. 1 Outfall—This outfall and the sewers draining thereto were constructed by the Board in 1932 and 1933. The area drained is about 80 acres.

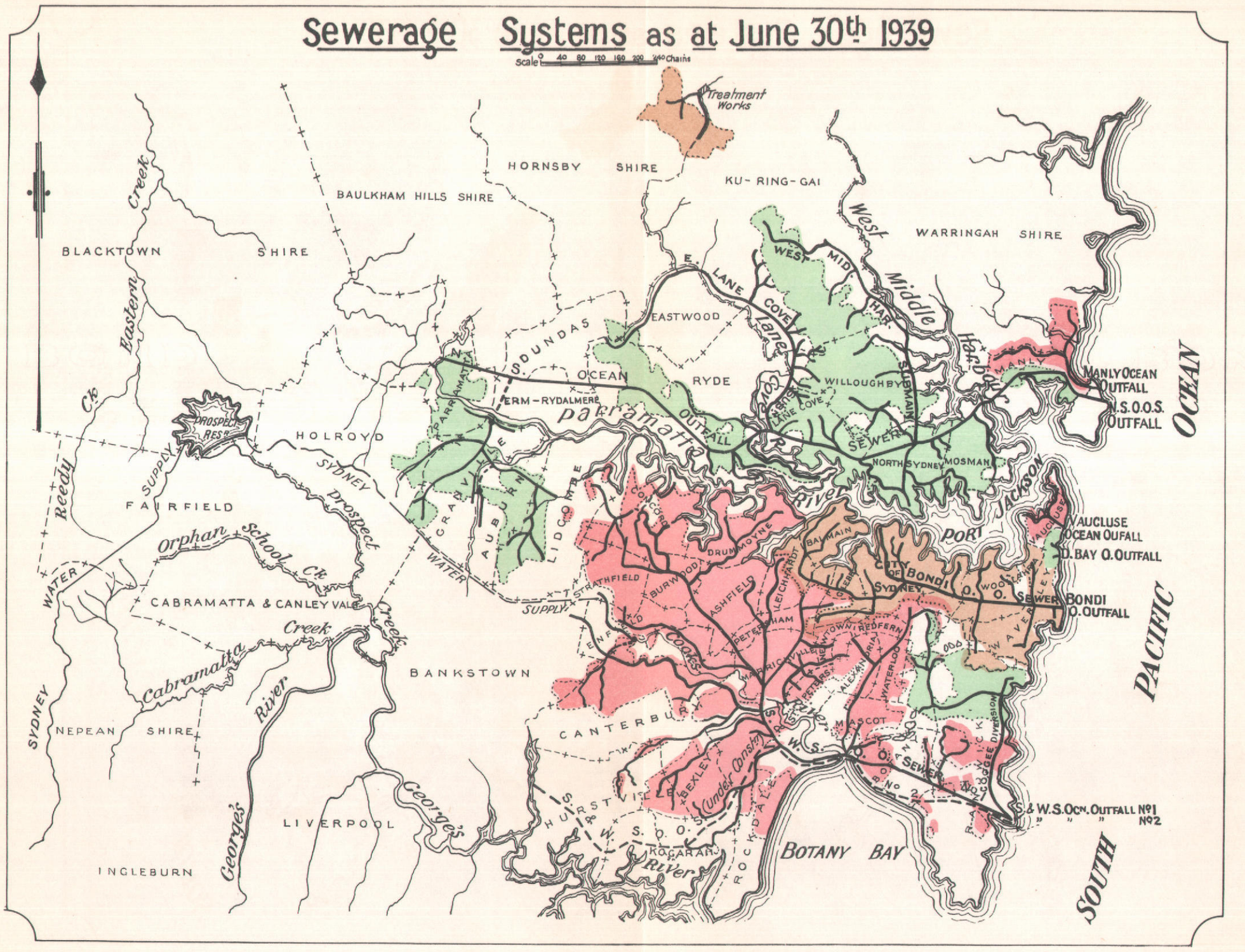
Diamond Bay No. 2 Outfall—This outfall is about 16 chains south of Diamond Bay No. 1 Outfall, and was constructed by the Board in 1935. The area sewered is about 69 acres.

The total number of houses drained to these two outfalls at 30th June, 1938, was 438. Population served about 1,890.

The two outfalls at Diamond Bay are of somewhat unusual construction. They are comparatively small and in view of the solid nature of the sandstone cliffs at these sites, the expense of sinking and concrete lining a shaft in each case from the surface down to the level of discharge of the sewage into the ocean was avoided by boring a hole of about the diameter of the outfall sewer down to a rock ledge, which projects from the cliff face into the ocean, in the case of No. 1 Outfall, 80-ft. from the surface and 30-ft. above high-water, and in the case of No. 2 Outfall 59-ft. from the surface and 19-ft. above high water. Shallow shafts were sunk into the rock ledges and the sewage is conveyed to the ocean through a tunnel in the case of No. 1 Outfall and through a 12-inch cast iron pipe encased in concrete in the case of No. 2 Outfall where conditions did not favour tunnelling.

REFERENCES

Parliamentary Standing Committee 1910.


Sewerage Systems as at June 30th 1939
Scale 0 40 80 120 160 200 240 Chains
Treatment Works
HORNSBY SHIRE
KU-RING-GAI
BAULKHAM HILLS SHIRE
WARRINGAH SHIRE
BLACKTOWN SHIRE
Eastern Ck
Reedy Ck
West Middle Harbour
E. LANE COVE
Lane Cove
EASTWOOD
WEST MID HAR
SOUNDAS
OCEAN
RYDE
WILLOUGHBY
SUBMAIN SEWER
MANLY
Manly Ocean Outfall
N.S.O.O.S. Outfall
PARRAMATTA
FERM-RYDALMERE
parramatta River
OUTFALL
PROSPECT RES.
HOLROYD
NORTH SYDNEY
MOSMAN
SYDNEY WATER SUPPLY
FAIRFIELD
GRANVILLE
AUBURN
LIDCOMBE
CONCORD
DRUMMOYNE
BALMAIN
JACKSON PORT
Vaucluse Ocean Outfall
D. Bay O. Outfall
Orphan School Ck
CITY OF SYDNEY
BONDI O. SEWER
Bondi O. Outfall
CABRAMATTA & CANLEY VALE
STRATHFIELD
BURWOOD
ASHFIELD
LEICHHARDT
PETERSHAM
Cooks River
Cabramatta Creek
Cabramatta River
BANKSTOWN
CANTERBURY
MASCOT
BOTANY BAY
SOUTH PACIFIC OCEAN
NEPEAN SHIRE
LIVERPOOL
INGLEBURN
George's River
S. & W.S.O. Outfall No 1
" " " No 2

CHAPTER XXXIII

WOLLONGONG SEWERAGE SYSTEM

In 1923 an Act was passed authorising the construction of a sewerage scheme for the town of Wollongong in accordance with surveys and plans prepared by the Public Works Department and as recommended by the Parliamentary Standing Committee on Public Works. Act No. 50 of 1924, which reconstituted the Metropolitan Board of Water Supply and Sewerage and renamed it the Metropolitan Water Sewerage and Drainage Board, provided that this reconstituted Board should be the sole constructing authority of Water Supply, Sewerage and Drainage Works within the area of its operations as defined in the Act. The Municipality of Wollongong being within that area, the responsibility for construction of the Wollongong Sewerage Scheme, which had not been commenced, passed to the Board, which then took over the plans, etc., from the Public Works Department. The scheme authorised by the Act of 1923 referred to above was based on an estimate compiled in 1915 giving probable cost £43,000. In 1927, when the Board proceeded to deal with the matter, it was found that a much larger scheme was necessary to meet the development which had taken place in the interim and to provide for the future increase of the population following industrial expansion then indicated. Moreover, construction costs were stated to have advanced about 80 per cent since 1915. The extra cost was, however, to a great extent offset by the increase in ratable values. The Board's preliminary estimate to sewer the three areas then embraced in the scheme was £138,400. On account of the topography of the areas to be served, the scheme adopted was wholly by pumping.

Treatment Works

The sewage is pumped to treatment works consisting of Imhoff septic tank, constructed on land acquired for the purpose adjacent to the ocean beach to the south of the township. The effluent discharges on to the loose sand and percolates through to the sea. An area of 56 acres 2 roods 34 perches was appropriated from the Crown by notification in the Government Gazette of 12th November, 1926, in connection with the treatment works. Only about 13 acres of this area is at present required for this purpose, and the balance is leased to the Wollongong Golf Club, excepting a small area of 1-3/5

acres over which permissive occupancy is granted to the Wollongong Racing Club. For the purpose of economical reticulation, the township has been divided into four areas, an additional area having been recently added to the three embraced in the original layout. Further areas will have to be dealt with in the near future owing to the growth of the district.

Pumping Stations

Pumping Station No. 1 is situated in Banks Street at the southern end of the town, on land acquired for the purpose, and pumps the sewage from the whole of the areas to the treatment works. It receives into its collecting wells not only the sewage from area No. 1, but also the sewage pumped into its reticulation lines from areas Nos. 2 and 3. The sewage from area No. 4 flows direct to No. 1 Pumping Station through No. 1 area.

Pumping Station No. 2—is situated on Smith's Creek, near Mt. Keira tramway, at the eastern extremity of the town, on an area of about 1¾ acres acquired for the purpose, and pumps the sewage from area No. 2 into the reticulation system of area No. 1 as above described.

Pumping Station No. 3—is situated in Stuart Park near Fairy Creek, at the northern extremity of the town, and pumps the sewage from area No. 3 into the reticulation system of area No. 1, as above described.

The reticulation of area No. 1 was completed on 1st June, 1929, No. 2 on 31st March, 1930, No. 3 on 10th December, 1931, and part of No. 4 on 24th November, 1932.

The cost of the Wollongong Sewerage Works to the 30th June, 1938, is £226,035 of which £31,900 represents a grant by the Government from Unemployment Relief Funds and is not included in the Capital Cost on which interest is payable.

STATISTICS

Year	No. of houses served	Approximate population served
1930 ..	986	4,500
1938 ..	1,650	9,075

REFERENCE

Parliamentary Standing Committee 1916.

CHAPTER XXXIV

STORMWATER DRAINAGE

It has been related earlier how the Tank Stream, the original source of water supply to the early settlement at Sydney Cove, gradually became transformed into an open sewer as the settlement developed into a City and the slop water from houses, in addition to stormwater, contaminated by street detritus, etc., found its way into the stream. A made channel (stone invert, brick sides) with proper grade to the outlet, had to be constructed to take the place of the natural stream which, in dry weather, would otherwise have become a chain of fetid pools, and later, in connection with the layout of the City, the open channel had to be covered in.

As the City spread, a similar fate overtook the other streams which meandered along the valleys into Blackwattle Bay, Woolloomooloo Bay, Rushcutters Bay, Double Bay, etc. Hence it is found that the Government at the same time as it constructed the main sewers to divert the old City system of sewerage from the Harbour to the ocean, constructed graded stormwater channels to take the place of the creeks running through settled areas in the City or adjacent suburbs. Between 1880 and 1894, the Government had constructed a number of these stormwater channels along the courses of the creeks flowing into the Harbour and Parramatta River, leaving the Councils to construct the subsidiary drains from the street gutters. Some of these channels traversing sewered areas are used by the Board as outlets for stormwater relief lines of pipes from its sewers.

In order that the expenditure on these stormwater channels might become revenue producing, an Act was passed in 1894 (57 Vic. No. 12) empowering the Governor by proclamation to transfer stormwater drains to the Board and on their transfer the Board became responsible for their maintenance. This Act also authorised the proclamation in the Gazette of drainage areas in respect of stormwater drains so transferred within the boundaries of which all lands became ratable in respect of any drainage rate levied by the Board. The financial aspect of the stormwater drainage system formed one of the subjects dealt with by the Committee previously referred to in Chapter II (Finance), appointed in 1904 to investigate and report on the Capital Account of the Board.

Act No. 50 of 1924 made the Board, as reconstituted thereby, the sole constructing authority for stormwater drains as well as water and sewerage works in its area of operations, and the future construction of the former therefore became a matter for determination by the Board alone. On account of the numerous requests from Municipal Councils for construction of these drains made to the reconstituted Board, the latter body found it necessary to lay down a policy which, in its opinion distinguished its responsibility from that of the Councils in this direction. The policy laid down in 1926 was that the Board would construct new main stormwater drains where such works would traverse more than one municipality or shire also in any case where the work, although entirely within the one municipality or shire was of such magnitude as to be beyond the financial resources of that municipality or shire. This policy has been generally adhered to and the Board, before embarking on these drainage schemes, requires to be satisfied that the expenditure will be rendered effective by the construction by the councils concerned of the subsidiary drains.

The statement of drainage rates opposite page 25 gives particulars of the proclaimed drainage areas under the Board's control.

REFERENCE

Parliamentary Standing Committee 1892.

EXPANSION OF SYDNEY SEWERAGE SYSTEMS UNDER BOARD CONTROL

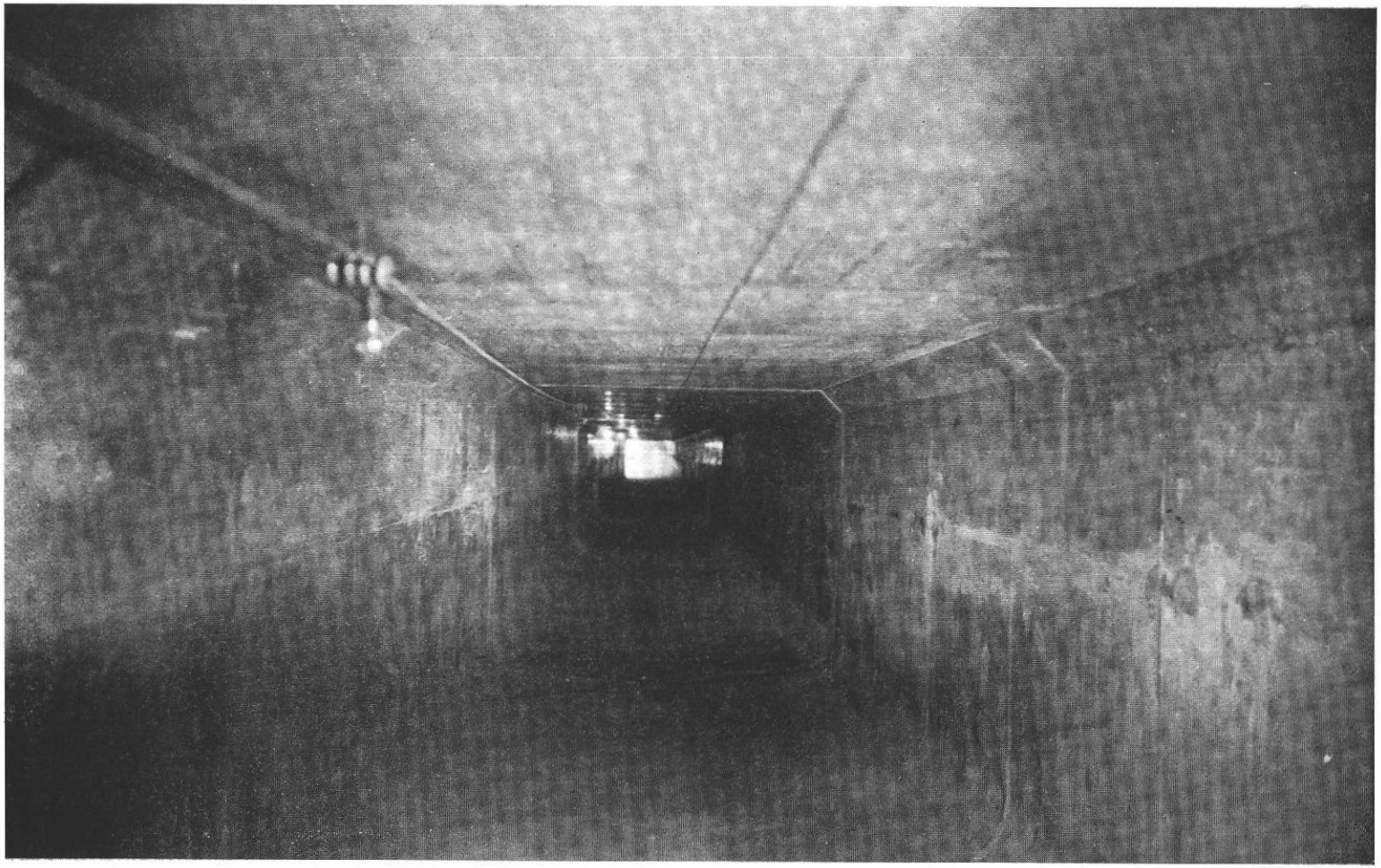
STATEMENT SHOWING INCREASE IN THE NUMBER OF HOUSES CONNECTED TO SEWERS DRAINING TO THE DIFFERENT OUTFALLS AND THE POPULATION SERVED IN EACH CASE OVER QUINQUENNIAL PERIODS FROM 1906

	Bondi Ocean Outfall		Sewage Farm (Botany Bay)				Treatment Works Located as under						Manly Ocean Outfall		Coogee Ocean Outfall	
			Western Suburbs		Southern Suburbs		North Sydney (Folly Point, Middle Harbour)		Chatswood (Scott's Creek, Middle Harbour)		Mosman (Balmoral)					
	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served	No. of Houses	Population Served
1906 ..	46,127	221,547	23,660	113,638	10,939	52,540	5,462	26,233	831	3,991	222	1,066	837	4,020	623	2,992
1911 ..	50,518	242,637	32,026	153,820	11,234	53,956	7,735	37,151	1,139	5,470	538	2,535	1,317	6,325	2,392	11,488
1916 ..	53,565	257,272	43,287	207,907	11,479	55,133	10,858	52,150	1,731	8,313	691	3,318	2,000	9,606	4,815	23,126
				* S. & W.S.O.O.S. Outlet												
1921 ..	55,875	268,367	64,091	307,829	—	—	12,219	58,687	2,442	11,728	818	3,928	2,568	12,334	6,764	32,487
1926 ..	57,784	265,575	77,783	357,490	—	—	14,043	64,541	3,553	16,329	1,073	4,931	3,324	15,277	8,391	38,565
								† N.S.O. Outfall Blue Fish Point								
1932 ..	59,076	256,803	97,134	422,241	—	—	32,567	141,568	—	—	—	—	3,422	14,875	11,021	47,908‡
1938 ..	62,688	266,324	115,278	485,537	—	—	47,779	203,070	—	—	—	—	4,494	19,100	11,364	52,691

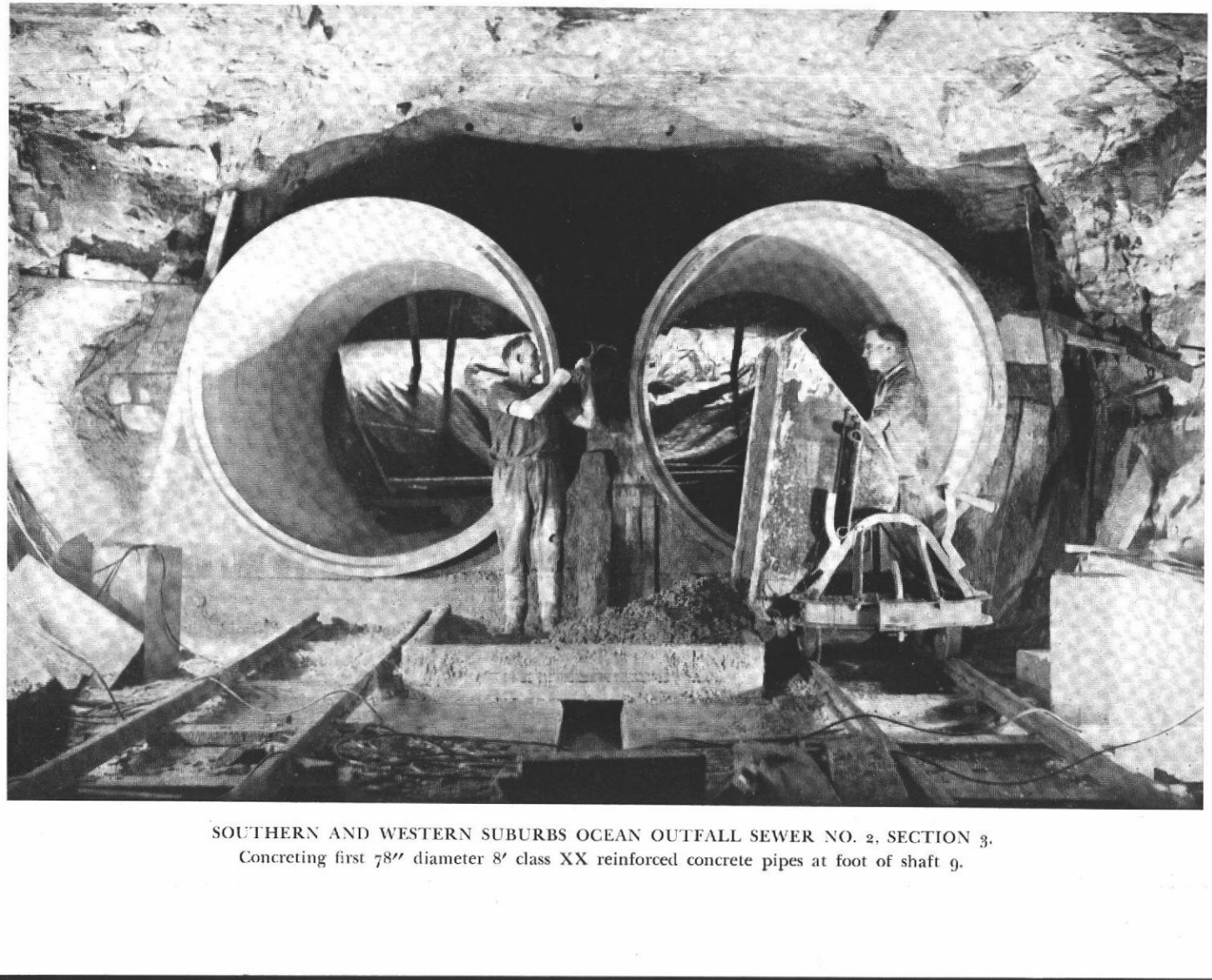
* On completion of the Southern and Western Suburbs Ocean Outfall Sewer to Miranda Point in 1916, the Sewage Farm ceased to be used for disposal of sewage.

† The Northern Suburbs Ocean Outfall Sewer from Blue Fish or North Point, was completed in 1927 to a point which enabled the sewage to be diverted from the Treatment Works, which were then closed down.

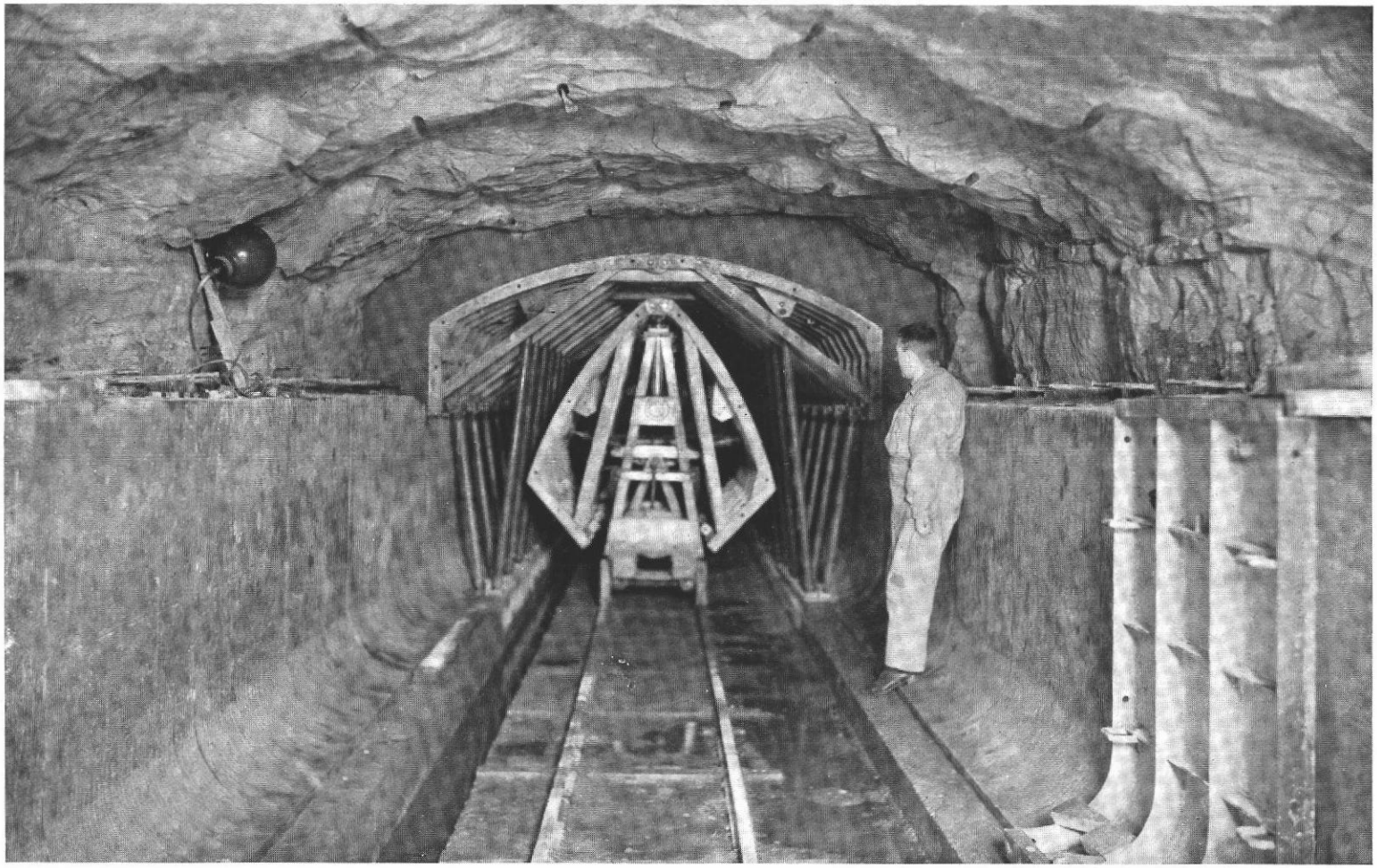
‡ The Coogee diversion sewer having become available in July, 1936, the Coogee flow was diverted to the Southern and Western Suburbs Ocean Outfall Sewer outlet.



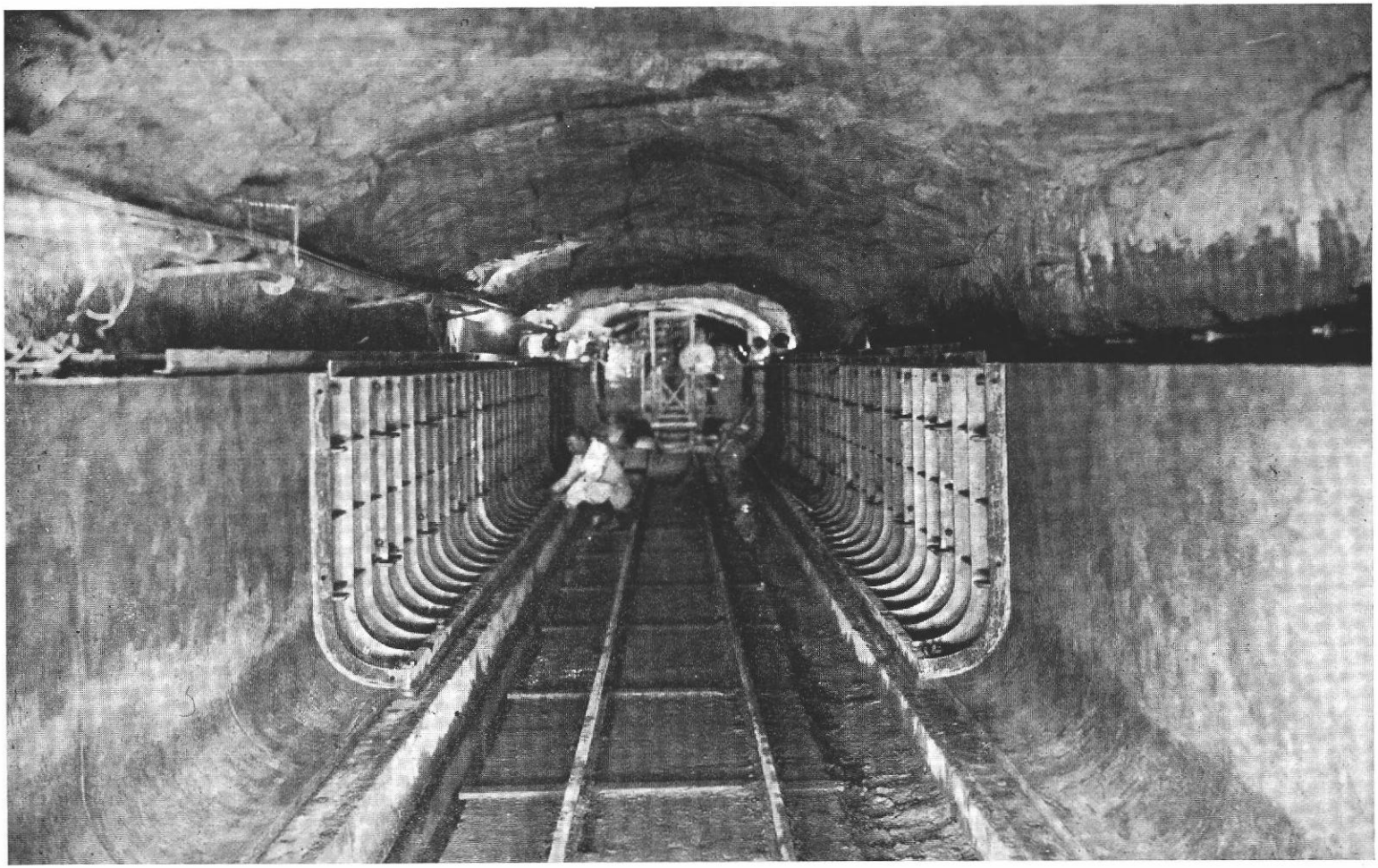
NORTH GEORGES RIVER SUBMAIN. SECTION 3.
Completed tunnel at Salt Pan Creek looking upstream.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 3.
Concreting first 78″ diameter 8′ class XX reinforced concrete pipes at foot of shaft 9.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 3.
Collapsed steel roof forms being transported through forms in position during setting of concrete.



SOUTHERN AND WESTERN SUBURBS OCEAN OUTFALL SEWER NO. 2, SECTION 3.

A length of sewer walls in tunnel concreted and stripped. A further length of steel wall forms erected ready for placing concrete.

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